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GAS-ENGINE PRINCIPLES

GAS-ENGINE PRINCIPLES

With Explanations of the Operation, Parts, Installation, Handling, Care, and Maintenance of the Small Stationary and Marine Engine, and Chapters on the Effect, Location, Remedy, and Prevention of Engine Troubles

BY

ROGER B. WHITMAN

AUTHOR OF "MOTOR-CAR PRINCIPLES"



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E.V.

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PREFACE

DURING the last few years the production of low-power stationary engines has shown a remarkable increase, and the appearance of this book is due to the fact that these engines have gone into the hands of users who have little or no knowledge of their operation, care and handling.

It is not the purpose of the book to instruct in engine design, or to compare the merits of different constructions, but to explain in a simple and practical manner the use of engines as they exist.

R. B. W.

FLUSHING, N. Y.



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GAS-ENGINE PRINCIPLES

CHAPTER I

GAS-ENGINE PRINCIPLES

IN order to do work of any kind, whether it is hauling a load, turning a grindstone, hoisting a bale of hay, or anything else, it is necessary to exert pressure, and the first step in doing work is therefore to produce the pressure that will be required for it. Pressure may be obtained from many sources; from wind; from running water; from gravity; but it is usually the case that it cannot be directly applied, or, in other words, that the form in which it exists is not suitable for the work that is to be done. Windmills, water wheels and pile drivers are thus used to convert the pressure from these sources into useful work.

On first thought it would hardly appear

possible to obtain pressure and work from heat; but, nevertheless, heat is the most generally useful source of pressure that we have, for it is the force that operates steam engines and all classes of gas engines.

Power may be obtained from heat because substances tend to become larger, or to **expand**, when they are heated. The mercury in a thermometer stands higher in the tube in summer than in winter because it occupies more room when warm than when cold; the only direction in which it may move in order to find room for itself is upward. The rails of a railroad will lengthen on a hot summer day, and spaces are left between the rail ends to permit them to do so. Great force is certainly required to stretch a steel rail, even by only a half inch, but sufficient force to do this is produced by the simple heating of the rail by the rays of the sun.

Heat acts in the same way and to a far greater extent on air and on all other gases than on metals; the operation of steam and

gas engines depends on this simple fact. As an example of the expansion of heated air, fill a large and tight paper bag three-quarters full of air, twist the neck tightly to prevent leakage, and hold it over a stove. As the air becomes heated the bag is seen to swell, for the air is now expanding and occupying more room. Then if the bag is moved away it will shrink, for as the air cools it does not take up so much space. If instead of partially filling the bag with air before heating it is completely filled, the effort of the air to expand when heated will burst the bag.

The most familiar example of the power that a heated gas can produce is the steam boiler and engine. Water is heated in a boiler and turned into the gas that is known as steam, and, being hot, this gas tends to expand. This it cannot do, however, for the boiler confines it, but in striving to expand it produces pressure, as indicated by the pressure gage. When the engine throttle is opened the steam finds an escape from the

boiler and rushes to the engine cylinder, where it has its desired opportunity to expand. In order to expand, however, and to make room for itself, it must move the piston, and by this movement of the piston the heat of the gas is converted into work. When the piston reaches the end of the cylinder the valves change, and direct the further flow of steam from the boiler to the other side of the piston, which is thus pushed back to where it started (Fig. 1).

The operation of a steam engine is thus due, first, to the production of a hot gas, and, second, to giving the gas the opportunity to expand that it desires, but requiring it to perform the work of pushing the piston in order to do so. The piston is connected to a crank, and its back-and-forth or **reciprocating** motion is converted to the round-and-round or **rotary** motion that is necessary for the driving of machinery.

The first step in producing power with a steam engine is the heating of the gas, and . . .

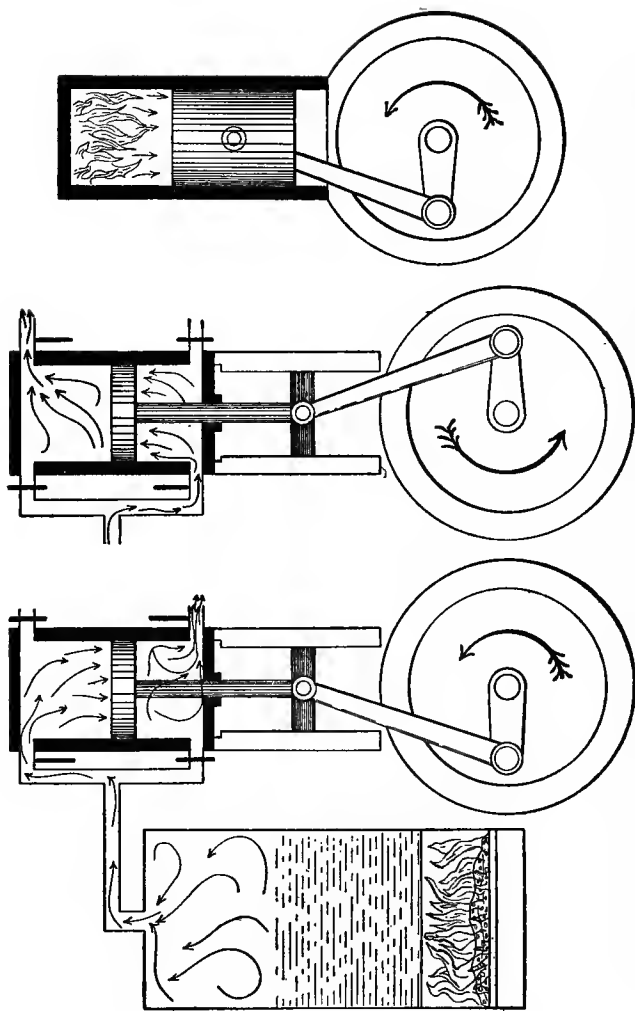


FIG. 1.—STEAM ENGINE (EXTERNAL COMBUSTION) AND GAS ENGINE (INTERNAL COMBUSTION).

the heat is applied in a boiler away from the cylinder; a steam engine might therefore be called an **external combustion engine**. If the heat is applied to the gas inside of the cylinder the engine could be called an **internal combustion engine**, and this is the true name of a gas engine (Fig. 1).

When a fire is built under a boiler only a small part of its heat is actually applied to heating the water, for most of it passes up the chimney or is otherwise wasted. When the fire is produced inside of the cylinder a far greater proportion of the heat is utilized in heating the gases, and this is the chief reason for the cheapness with which a gas engine produces power.

There is no difference in the principle under which steam engines and gas engines operate; in both cases it is the expansion of a hot gas that produces power, and the difference between the two classes of engines is in the method of heating the gas. In the steam engine the gas is heated by the fire

under the boiler, while in the gas engine the gas is of a kind that will burn, and it is heated by its own burning. This gas is taken into the cylinder, and at the right instant it is set on fire; it is heated very suddenly and intensely by its own flames, and instantly endeavors to expand and to occupy more room. As is the case with the steam in the steam engine, the gas must move the piston in order to make room for itself, and this movement of the piston turns the crank shaft and develops power.

In order that a gas engine may run, it is necessary first to provide a gas that will burn and then to get it into the cylinder. The gas must next be set on fire in order that it may expand and develop power, and, finally, the burned and useless gases must be driven out of the cylinder to make room for a fresh charge.

In a steam engine the piston is always moving under the pressure of the steam, but in a gas engine the pressure of the hot gas

moves the piston for only a part of the time. No power is being produced by the engine while the fresh gas is going into the cylinder, or while it is being prepared for burning, or while the burned gas is being driven out of the cylinder. These things are done by keeping the piston moving, and the power for this is supplied by an outside force.

In a foot-power grindstone the treadle is pushed downward by the foot, and the spin or **momentum** of the heavy stone brings the treadle upward to the point at which it may again be pressed down. A heavy wheel does the same thing for the gas engine. This **fly wheel** is attached to the crank shaft, and the spin or momentum that it gains when the piston is being moved by the pressure of the hot gas is sufficient to keep the crank shaft turning and the piston moving during the time when pressure is not being developed.

There are certain definite processes that the gas engine must perform in order to run, and if these are interfered with or are prevented,

the engine will run poorly or not at all. The first step is to get the gas into the cylinder, and this is done by working the engine as a pump. In a water pump water is sucked into the pump cylinder by moving the plunger, and in a gas engine the piston is moved from one end of the cylinder to the other to suck a charge of gas into the space between the top of the piston and the cylinder head, or, as it is called, the **combustion space**.

The gas that is thus drawn in is not in a condition to develop great power, however, and if it were to be burned immediately the results would be very poor. The power developed by the gas will be very greatly increased if the gas is compressed before it is burned, and the second step in the operation of the engine is the compression of the charge of gas. In explanation of the necessity for compression let us suppose that the engine cylinder contains one quart of gas, and that when the gas is burned and heated it becomes a gallon. If this quart of gas is compressed

to a pint before it is heated, it will still be capable of expanding to a gallon, and twice the pressure will be developed in expanding it from a pint to a gallon as would be developed in expanding it from a quart to a gallon. The same principle applies to a gun; if the charge of powder is rammed down hard, the bullet will be fired with much more force than would be the case if the powder is poured loosely into the barrel.

Another good result of compression is that it greatly improves the quality of the gas. The gas that is drawn into the cylinder during the first movement of the piston will not burn as readily as is desirable, for the gasoline vapor and air of which it is composed are not as well mixed as they should be; furthermore, some of the gasoline may not have turned to vapor, but have entered the cylinder as a liquid. The compression of the charge turns any liquid gasoline to vapor, and mixes the gasoline vapor thoroughly with the air.

The third step in the operation of the engine is the production of power. When the charge of gas is compressed it is set on fire, and the pressure produced by the sudden heating of the gas drives the piston from one end of the cylinder to the other. It is then that the engine delivers power.

The charge of gas having been burned and expanded, it is no longer of use, and the final step is to drive this useless gas out of the cylinder to make room for a fresh charge.

This succession of events is called the **gas engine cycle**, or **Otto cycle**, and must be repeated as long as the engine runs. The word cycle does not indicate any single step in the process, but all of the steps, taken as a whole and in their proper order. The steps necessary in using a gun are the inserting of a cartridge, its discharge, and the removal of the empty shell, and these might be called the **gun cycle**; if one step is omitted the others cannot be performed.

CHAPTER II

ENGINE TYPES

GAS engines are divided into two classes, according to the number of movements, or **strokes**, that the piston makes in going through the cycle. A stroke is the movement of the piston from one end of the cylinder to the other, and the piston makes this movement while the crank shaft makes one-half of a revolution. The movement of the piston toward the crank shaft is called an **outward stroke**, and the movement away from the crank shaft is called an **inward stroke**. During every revolution of the crank shaft the piston makes these two strokes.

The class of gas engines that is in most general use is the **4-stroke cycle**, or **4-cycle**, which requires the piston to make four

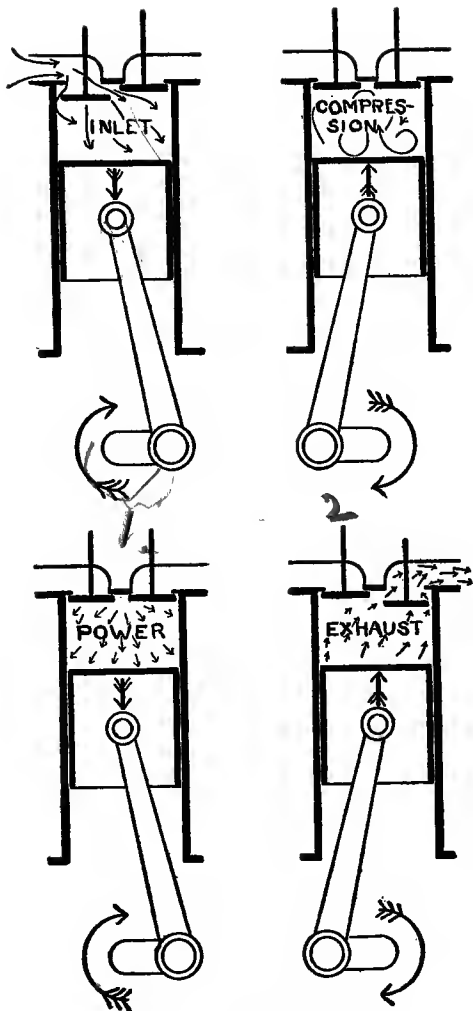


FIG. 2.—THE 4-STROKE CYCLE.

strokes in order to draw the fresh gas into the cylinder, to compress it, to deliver power, and to drive out the burned gases. These four strokes are named in accordance with the action that takes place during each one, and are illustrated in Figure 2. The four diagrams represent a cylinder, open at the end toward the crank shaft and with the other end closed, and in which the piston slides as the crank shaft revolves.

Starting at the closed end, the piston makes an outward stroke, and as the first diagram shows, the inlet valve opens to permit a charge of fresh gas to be drawn into the cylinder. This movement of the piston is called the **inlet stroke**, or **suction stroke**. When the piston reaches the end of the stroke the inlet valve closes, the cylinder then being filled with gas. The piston now makes an inward stroke, and, as the gas cannot escape, it is compressed between the piston and the closed end of the cylinder. This is called the **compression stroke**. When the piston

reaches the end of this stroke the gas is set on fire, or **ignited**, and the pressure drives the piston outward on the **power stroke**, or **working stroke**. During this stroke the valves remain closed. The piston next makes an inward stroke, and as the **exhaust valve** is open at that time, the burned gases are pushed out. This is called the **exhaust stroke**, or **scavenging stroke**, and when it is completed everything is ready for another inlet stroke and a repetition of the cycle.

The performing of the cycle thus requires two revolutions of the crank shaft, or four strokes of the piston, but power is developed during only one of these strokes. The other three strokes are the so-called **idle strokes**, and not only is no power developed during them, but power is required to move the piston through them. This power is obtained from the spin or momentum of the flywheel, which is thus seen to play an important part in the operation of the engine.

The engine actually develops power for

only one-quarter of the time that it runs; on an hour's run it will be developing power for only fifteen minutes, the remaining forty-five minutes being taken up by the idle strokes. For three-quarters of an hour, therefore, the engine and the machinery will be kept running by the momentum of the flywheel, and it is necessary to give the flywheel considerable weight in order that the momentum may be sufficient for the work required of it.

Pressure is developed in the cylinder with great suddenness, and if the flywheel is too light in weight it will speed up, permitting the piston to move too fast on the power stroke. Furthermore, it will not have sufficient momentum to move the piston steadily and at proper speed through the succeeding idle strokes, the result being jerky and unsteady operation. A flywheel of proper weight will prevent the piston from moving too rapidly during the power stroke, and will drive it steadily and smoothly through the idle strokes at almost constant speed.

In another class of gas engines the cycle is performed in two strokes of the piston, or one revolution of the crank shaft, and these are called **2-stroke cycle engines**, or **2-cycle engines**. When a 4-cycle engine makes one hundred revolutions it performs the cycle fifty times, but during one hundred revolutions a 2-cycle engine will perform the cycle one hundred times.

In a 4-cycle engine the action takes place between the piston and the cylinder head, while in a 2-cycle engine the gas is acted on first by one end of the piston and then by the other. To make this possible the crank shaft of the 2-cycle engine is enclosed; the gas is sucked into the **crank case**, or **base**, and then passes to the combustion space.

The principle of the 2-cycle engine is illustrated in Figure 3. In Diagram 1 the piston is shown making an inward stroke, and, as the space below it is tightly enclosed, suction is created there. As a result a charge of gas is sucked into the crank case, a valve being

arranged to permit it to enter. During the succeeding outward stroke of the piston the valve closes, and, as the gas in the crank case cannot escape, it is compressed (Diag. 2, Fig. 3). It will be seen from the diagrams that there is a passage from the crank case below the piston to the combustion space above it, but this passage is closed by the piston until the end of the stroke is reached. By the time that the piston reaches the outer end of its stroke the gas below it is compressed and struggling to escape. The opening of the passage gives the gas its opportunity to escape from the crank case, and it flows to the combustion space (Diag. 3).

When the piston starts an inward stroke it closes the passage, and compresses the charge of gas above it (Diag. 1). On the completion of the inward stroke the gas is set on fire, and the piston is driven outward on the power stroke (Diag. 2). When the piston reaches the end of its stroke it uncovers a passage on the opposite side of the

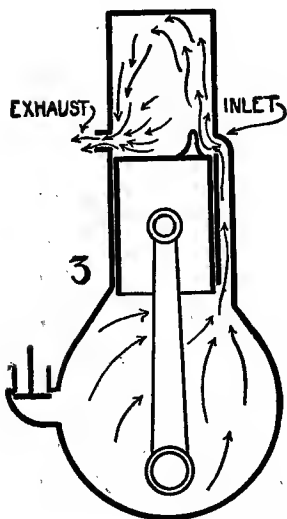
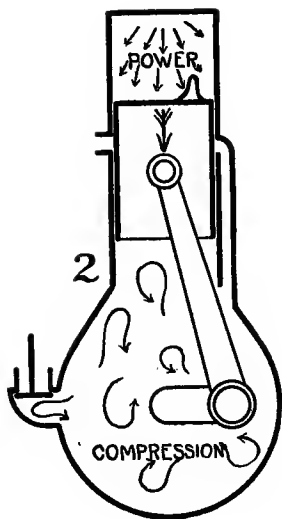
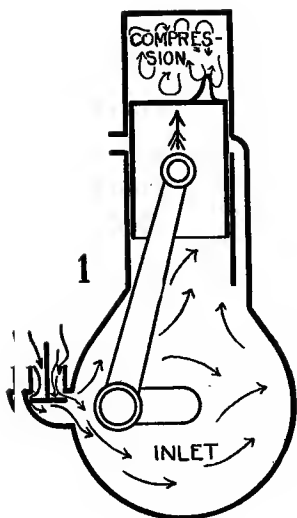


FIG. 3.—THE 2-STROKE CYCLE.

cylinder from the inlet passage, and the burned gas begins to rush out. At the same time the fresh gas is entering the cylinder, but is deflected upward by a ledge on the piston. In this way the cylinder is filled from the top, and the fresh gas assists in getting rid of the burned gas (Diag. 3).

Thus, while the piston is making an outward stroke it is developing power, and at the same time is compressing the gas in the crank case; while it makes an inward stroke it compresses the charge above it and at the same time sucks into the crank case another charge of fresh gas. A 4-cycle engine does only one thing at a time, but a 2-cycle engine does two things at a time, and is therefore able to deliver two power strokes to every one delivered by a 4-cycle engine. This does not mean that it will develop twice the power, however, for, while the 4-cycle engine allows full strokes for the inlet and for the exhaust, the 2-cycle engine allows only a small part of a stroke for the fresh gas to enter and for

the burned gas to escape. The charges cannot be so full, therefore, nor can the burned gases be so completely removed. The 2-cycle engine is, nevertheless, a success for certain kinds of work, and in its own field is very satisfactory.

CHAPTER III

ENGINE PARTS

GAS engines are produced in a great variety of forms, but whatever their appearance may be, they must operate in accordance with one or the other of the types explained in the preceding chapter. If 4-cycle and 2-cycle operation are understood, there will, therefore, be no difficulty in understanding the action of any form of gas engine.

The difference in the appearance of engines is due to some being built with the cylinder standing upright, while others are built with the cylinder lying down. The position of the cylinder makes no difference in the operation of the engine, nor in the action of the engine parts, so that if the action of the parts is understood, and also the relation of each part

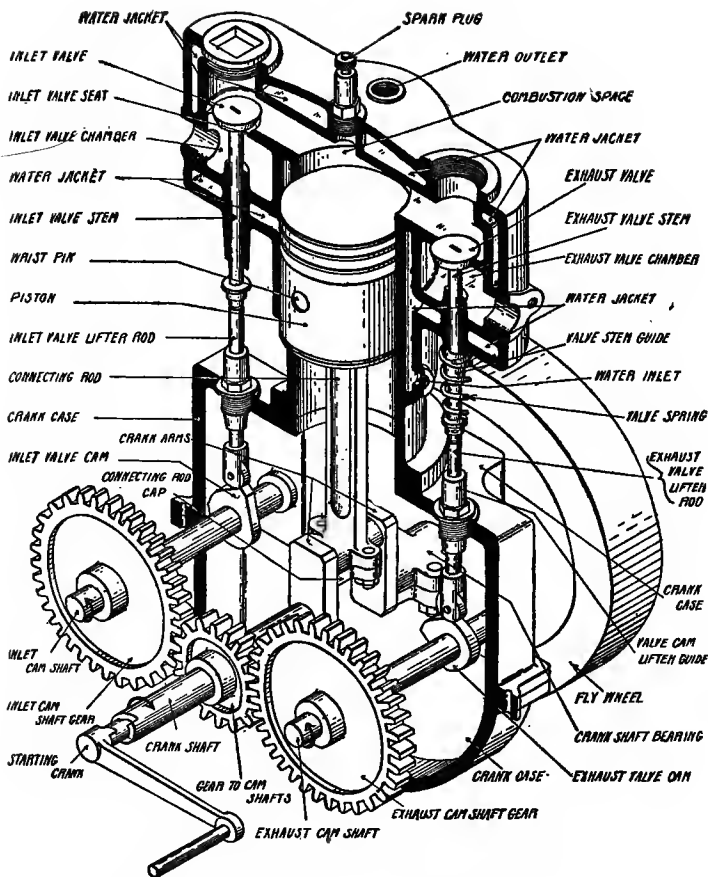


FIG. 4.—VERTICAL ENGINE, AUTOMOBILE TYPE.

to the others, it should be possible to start and operate an engine without previous knowledge of it. In the following description of the parts of an engine continual reference should be made to Figures 4, 5 and 6, in order that the position of each part may be thoroughly understood.

Figure 4 represents a 4-cycle engine with the cylinder standing upright, and called a **vertical engine**. The engine is shown in **section**, or cut in half, with part of the cylinder and crank case removed so that the interior construction may be seen. The heavy black lines show where the metal has been cut.

The engine shown in Figure 4 is of the kind frequently used in automobiles, while Figure 5 shows a 4-cycle vertical stationary engine. The automobile engine usually has four cylinders, which are so placed that the power stroke of one is immediately followed by the power stroke of another. The crank shaft is thus moving under power at all times, and for this reason, as well as on account of the

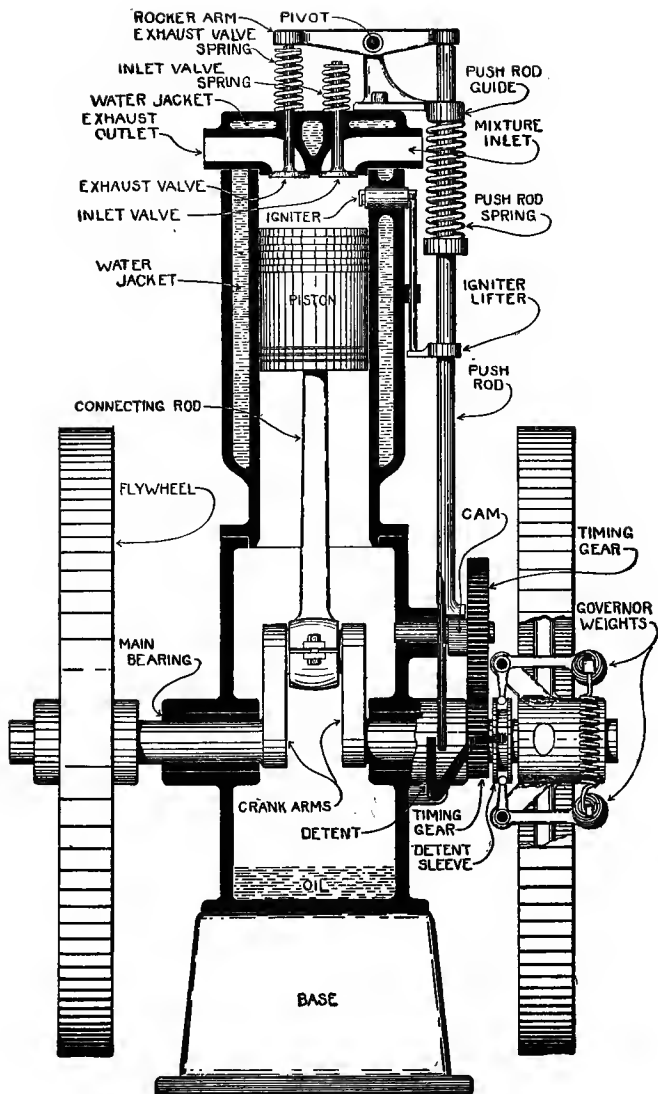


FIG. 5.—VERTICAL ENGINE, STATIONARY TYPE.

high speed at which the engine runs, a small and light flywheel is sufficient. A stationary engine, on the other hand, usually has but one cylinder and runs at low speed; two flywheels are required to carry the piston steadily through the idle strokes.

Figure 6 shows a 4-cycle **horizontal** stationary engine, in which the cylinder is lying down.

Some of the parts of a gas engine are acted on by the pressure of the burning gas, while others control the preparation and flow of the fresh gas, the setting on fire, or **ignition**, of the gas, the oiling of the bearings, and the cooling of the parts that would suffer from overheating. If any of these parts fail to work properly, the engine will not deliver its full power, and gasoline will be wasted, because it will not be doing all of the work of which it is capable.

It is of great importance to prevent a leakage of gas during the compression stroke, and of pressure during the power stroke; the

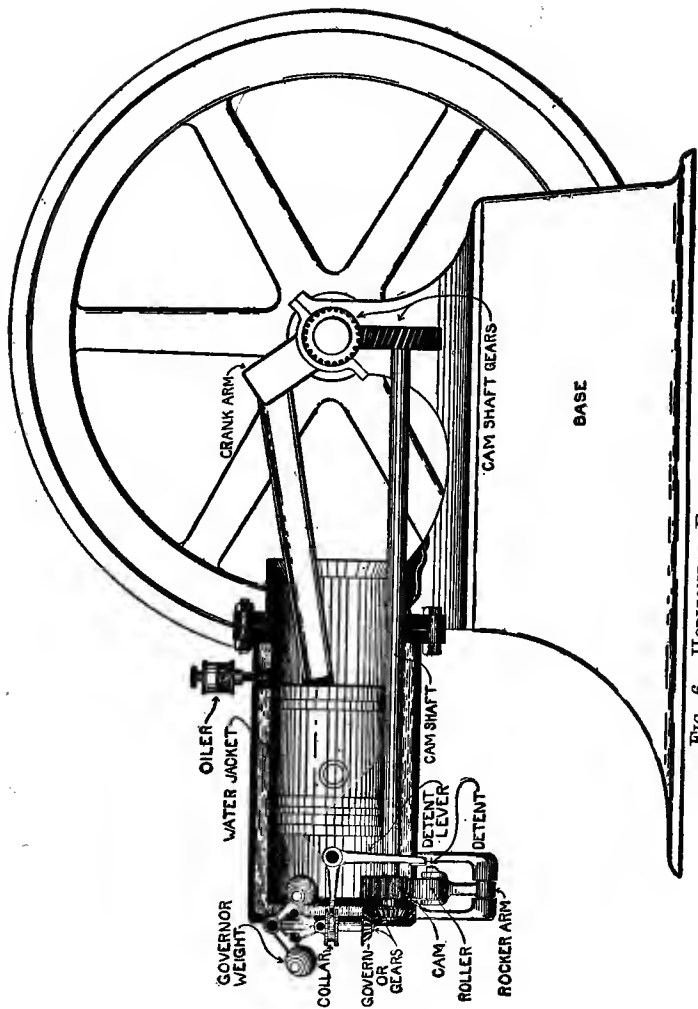


FIG. 6.—HORIZONTAL ENGINE, STATIONARY TYPE.

piston must, therefore, make a snug fit in the cylinder. At the same time, however, the piston must be free to slide easily, for if it binds, much of the power will be spent in moving it instead of being devoted to turning the crank shaft. To secure this action the inside of the cylinder, or the **cylinder walls**, should be as smooth as possible, and the cylinder is therefore made of cast iron with a fine grain that takes a high polish.

The cylinders of small stationary engines are frequently cast in one piece, as shown in Figures 4 and 6, but it is more usual for the head to be cast separately and bolted to the cylinder, as shown in Figures 5 and 7.

The intense heat produced in the cylinder during the power stroke makes it necessary to cool the cylinder in order that the lubricating oil may not be burned. On some small engines the cylinders are cooled by blowing air against them, but it is more usual to cool the cylinder by circulating water around it. This requires the cylinder to be made with

passages through which water may flow, and the water jacket is usually cast in one piece with the cylinder. The cylinder head must also be cooled, and when it is made sepa-

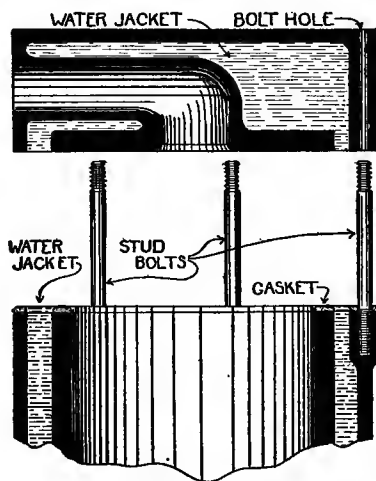


FIG. 7.—“BOLTED-ON” CYLINDER HEAD.

rately from the cylinder it must have passages and channels communicating with the cylinder jacket.

The cylinder head must fit tightly to prevent leakage of pressure as well as of water, and it is secured to the cylinder by bolts,

with a **packing** or **gasket** at the joint (Fig. 7). A gasket is made of a material that is soft enough to be pressed into the uneven spots in the metal, but that is sufficiently tough to resist being blown out by the pressure. A thin sheet of asbestos molded over fine wire gauze is frequently used, and is very satisfactory.

The piston is made slightly smaller than the cylinder, in order that it may not bind when it is expanded by the heat. The piston is a cylinder that is closed at one end and open at the other, the closed end, or **piston head**, being toward the cylinder head. It is long in proportion to its diameter in order that it may not twist and jam in the cylinder, and should be strong enough to resist the great pressure that acts against it, but at the same time should be as light in weight as possible. When the piston reaches the end of a stroke it must come to a stop before it can begin to move in the opposite direction on the next stroke; the part that brings it to a

stop is the **crank**, to which it is attached by the **connecting rod**. The heavier the piston is, the greater will be the shock of stopping its movement, and this shock will cause the

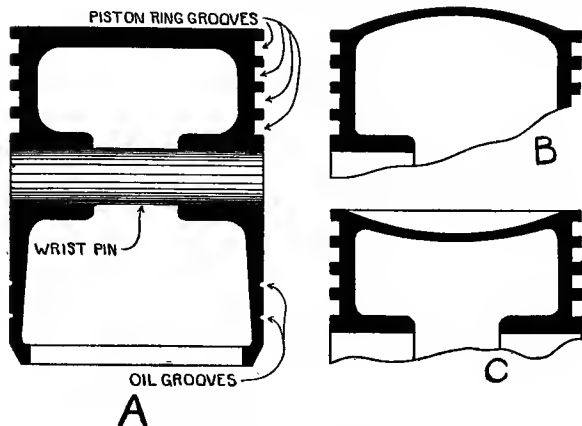


FIG. 8.—PISTON SECTIONS.

wearing of the crank shaft and connecting rod bearings.

The sides of the piston serve only as a guide, but the piston head and the part of the piston to which the connecting rod is attached must be heavy and strong in order to stand the strain. Figure 8, A, shows a piston

in section, and it will be seen that the upper part is heavier than the lower part. It also shows the heavy metal lugs that support the **wrist pin** (also called **piston pin** and **gudgeon pin**) that forms a sort of hinge on which the connecting rod swings. The piston head is usually flat, as shown in A, but sometimes it is arched and sometimes hollowed, as shown at B and C. The lower part of the piston has grooves cut in it to catch the lubricating oil and to spread it over the cylinder wall.

Deep grooves are cut in the upper part of the piston to contain the **piston rings**, or **packing rings**, which prevent the gas from leaking past the piston. The piston rings are made of cast iron, and fit the grooves just loosely enough to move freely. They are not endless rings, but are cut through so that they may act as springs. When they are off the piston they spring open to a larger diameter than the cylinder, and as they must be sprung in to get them into the cylinder, they maintain a constant pressure against its

walls. In some engines the rings are of equal thickness all around, while in others they are thinnest at the point where they are cut, to increase the elasticity. Figure 9 shows this, and also the two methods of making the cut, one being a straight cut at an angle, while in the other the ends overlap.

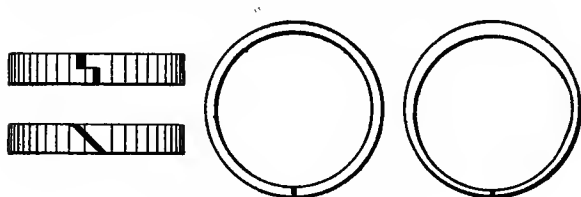


FIG. 9.—PISTON RINGS.

Piston rings should be free to spring in and out, but should not be permitted to slide around; they are usually secured by pins. These pins should be so placed that the cut in one ring will not be in line with the cuts in the rings above and below, as this makes it more difficult for the gas to escape by leaking through the cuts.

The wrist pin is a steel rod of sufficient strength to withstand the shock of passing to

the connecting rod the pressure that acts against the piston. Its ends are supported in the lugs that are cast in the piston, while its center passes through one end of the connecting rod. It is usually hollow, in order that oil may pass to the bearing. In a large number of engines it is firmly secured in the lugs, the connecting rod swinging on it, but in some cases it is attached to the connecting rod and turns in the lugs. Figure 10 shows various methods of securing it. In A, setscrews are screwed into the lugs, with their points catching in holes in the wrist pin; the setscrews are prevented from turning either by locknuts, as shown in A, or by **cotter pins**, or **split pins**, as shown in B, which is a view of a piston from the bottom. In D the end of the setscrew passes through the wall of the wrist pin, where it is secured by a cotter pin. In E the wrist pin is held in position by a piston ring passing across its ends. When the wrist pin is attached to the connecting rod it is frequently secured by a setscrew

and locknut, as shown at C. Whatever the method of securing the wrist pin may be, it must be prevented from moving endways,

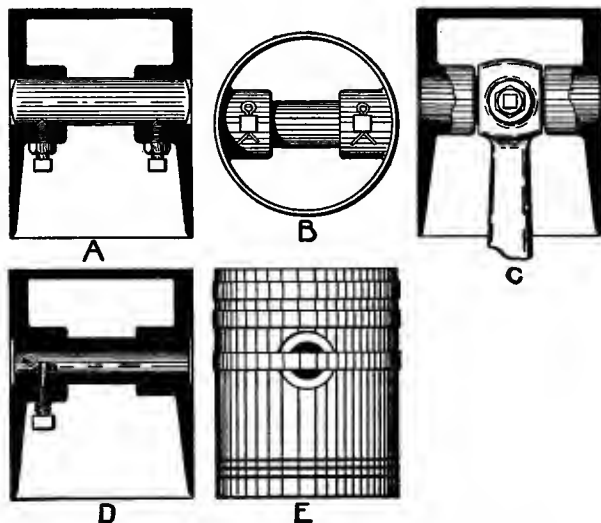


FIG. 10.—METHODS OF SECURING THE WRIST PIN.

for that would permit it to strike the cylinder wall and to wear a groove in it.

When the piston is making a power stroke the connecting rod receives the pressure lengthways, and must be strong enough to

resist bending. In some engines the connecting rod is a steel tube, while in others it is a flat steel bar that is thicker at the edges than at the center. This form is called the **I-beam section**, and is of great strength in proportion to its weight. The ends of the connecting rod form bearings for the wrist pin and for the crank, the **small end** being at the wrist pin and the **big end** at the crank. These bearings are subject to wear because of the great strains that they are under. The wear is greatest at the big end, however, for the crank pin revolves inside of this bearing, while the bearing at the small end only has a swinging motion on the wrist pin.

Speaking broadly, there are two methods of making bearings, according to whether the bearing metal is soft, like Babbitt metal, or hard, like white or yellow bronze. When Babbitt is used the wrist pin or other part is set in position in the bearing support, and the melted metal is poured in to fill the space between. When bronze is used it is cast or

molded in the proper form, either in one piece or in halves, and set into the supports.

The wrist pin bearing is frequently a tube that fits the wrist pin snugly, and that is set in the small end of the connecting rod. In this case it is not adjustable for wear, but it is more usual to make it adjustable. The big end bearing is invariably adjustable.

Various methods for the adjustment of the connecting rod bearings are shown in Figure 11. AF shows a complete connecting rod, the small end bearing, A, being non-adjustable. The small end of B is cut across, the parts being sufficiently elastic to permit the bearing to be drawn to a proper fit around the wrist pin by the bolt. In C the bearing is in two parts, and these, together with the block that supports them, are secured to the connecting rod by a U-shaped bolt and two nuts. D is called the **marine type**, and it consists of two blocks of bronze secured to the connecting rod by bolts. In E the end of the connecting rod is formed into a loop, into

which are set two blocks of bearing metal. The bottom of the lower block is cut at an angle to fit a wedge that may be moved by means of bolts. By moving the wedge to the left the lower block is forced against the upper to secure the proper adjustment.

F is a very usual form for the big end of the connecting rod. The lower part, or **bearing cap**, is hinged to the main part of the connecting rod, and may be drawn into position by the bolt. In G the bearing cap is separate, and the halves of the bearing are held between the cap and the main part of the connecting rod. This form is very general for automobile engines. H is the marine type of big end, the bearing blocks being secured between the flat end of the connecting rod and a steel plate next to the bolt heads. K is the same, but without the steel plate.

In order that bearings may be adjusted to take up wear, a metal plate, or a number of very thin sheets of metal, will be placed between the edges of the halves of the bearing.

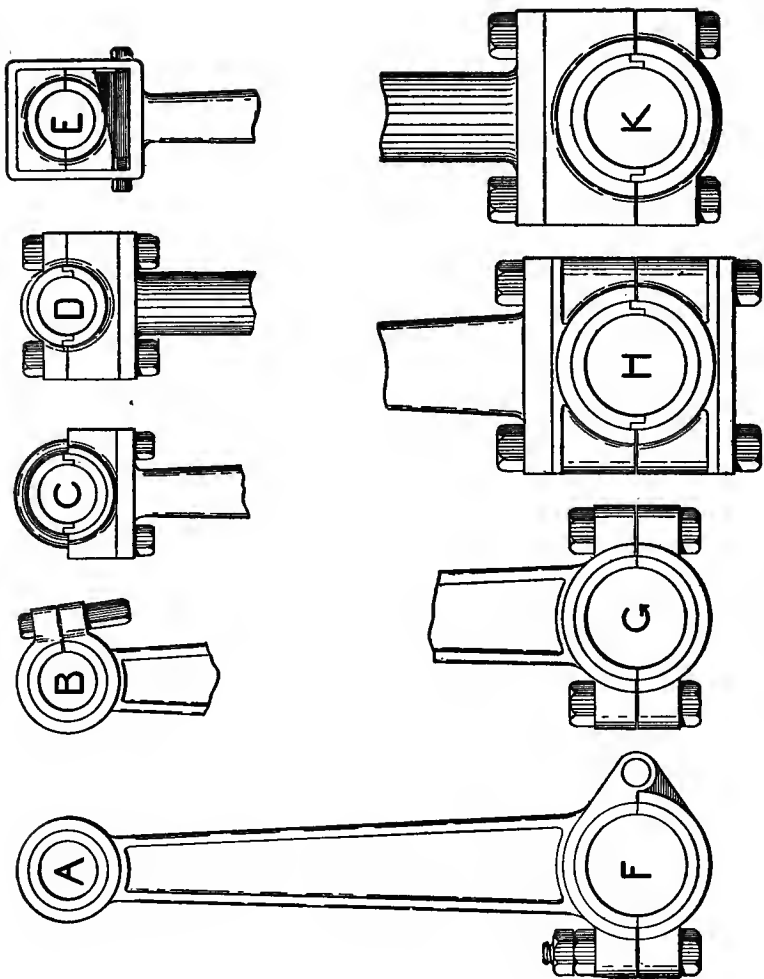


FIG. 11.—ADJUSTMENTS OF CONNECTING ROD BEARINGS.

When the bearing wears and becomes loose the metal plate may be filed thinner, or one of the thin sheets may be removed, to permit the bearing to be drawn tightly around the shaft. These metal plates or sheets are called **shims**.

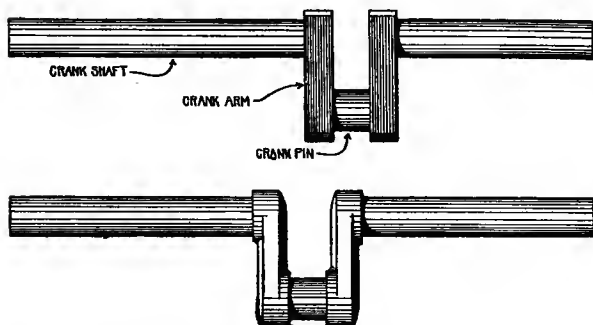


FIG. 12.—CRANK SHAFTS.

When an engine is running the greatest strain is on the crank shaft, and this should be made of high grade steel. The shaft is supported in the **main bearings**, and the **crank arms** project from it with the **crank pin** between their ends (Fig. 12). When the engine makes a power stroke the pressure tends

to drive the piston outward at high speed; the pressure is transmitted to the connecting rod and crank pin, and they tend to move at high speed also. The heavy flywheels secured to the crank shaft cannot speed up suddenly, but tend to revolve at constant speed. One part of the crank shaft is thus inclined to speed up, while other parts are not, and it will be seen that it must have great strength in order to resist this twisting strain.

The engine base is made of cast iron, and its main work is to keep the cylinder and crank shaft in the proper relation to one another. When the power stroke occurs, the tendency is to drive the cylinder in one direction and the piston and crank shaft in the other. The base must have sufficient strength to hold the cylinder rigidly in position, and to prevent its changing its relation to the crank shaft.

CHAPTER IV

VALVES AND VALVE MECHANISMS

THE gas enters and leaves the cylinder through the **valve openings**, which are round holes cut in the cylinder head, or in chambers, called **valve pockets**, that communicate with the combustion space. A valve opening is usually funnel-shaped, and it may be closed by a **valve disk**, which has a bevelled edge to fit. Figure 13 shows a section of a cylinder head and the two valves, one closed and one open. To open a valve it is only necessary to move the disk away from the opening, or from its **seat**, and this is done by means of the **valve stem**, which is a rod solidly attached to the valve disk.

The valve seats are bevelled in such a way that the valve disks must move inward in

order to open, so that during the compression and power strokes the pressure holds them to their seats. During the inlet and exhaust strokes one or the other of the valves

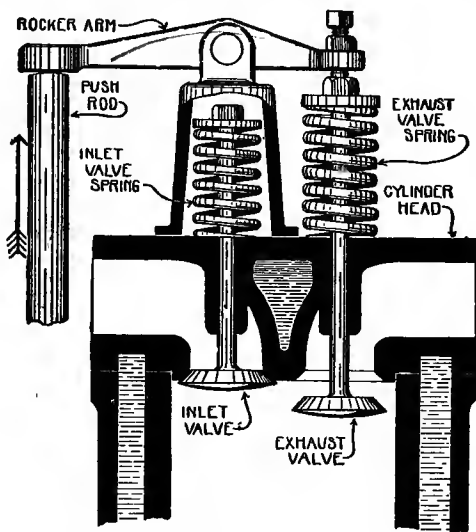


FIG. 13.—CYLINDER HEAD AND VALVES.

is open, but when the time comes for them to close the disks are drawn to their seats by the springs that surround the valve stems.

The exhaust valve is always opened by the

engine itself; a rod or lever is arranged to press on the end of the valve stem at the beginning of the exhaust stroke, the valve disk thus being moved from its seat. The rod or lever continues to hold the valve open for the entire exhaust stroke, and when the valve stem is released at the end of the stroke the spring draws the valve disk back to its seat. In Figure 13 the exhaust valve is opened by the **push rod**, which moves in the direction of the arrow, and presses against one end of the **rocker arm**. This causes the rocker arm to move on its pivot, and its other end presses downward on the valve stem.

When a valve is opened by the engine it is called a **mechanically operated valve**; the exhaust valve is always mechanically operated, and on some engines the inlet valve is mechanically operated also. On small stationary engines, however, it is usual for the inlet valve to be an **automatic valve**. When the piston makes an inlet stroke, violent suction is created, for the outside air struggles

to enter the cylinder in order to fill the space left vacant by the outward movement of the piston. It is necessary for the air and gas to enter the cylinder, but the only openings by which it can get in are the valves. The exhaust valve, however, is held to its seat by a spring that is too powerful for the suction

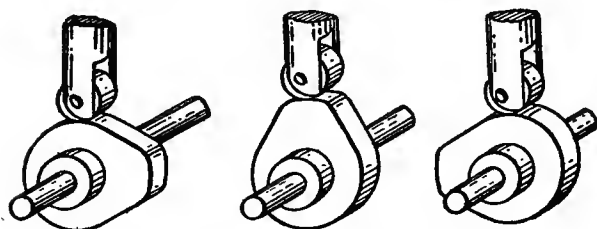


FIG. 14.—CAM IN THREE POSITIONS.

to overcome, and the air and gas, therefore, enter through the inlet valve. The spring of the automatic inlet valve is weak enough to permit the suction to draw the valve disk from its seat, and, as the suction continues as long as the piston is making an inlet stroke, the valve is held open. When the piston finishes the inlet stroke the suction

ceases, and the valve is then closed by the spring. The inlet valve shown in Figures 5 and 13 are automatic valves.

On vertical engines the valves are usually

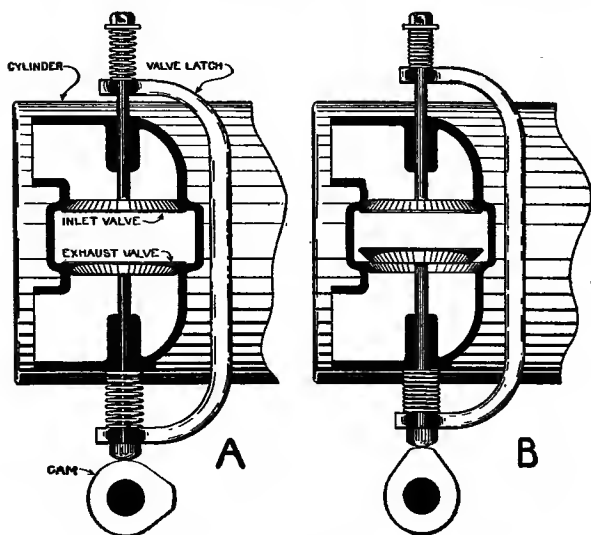


FIG. 15.—INLET VALVE LOCKED WHEN EXHAUST VALVE IS OPEN.

placed in the cylinder head, and the exhaust valve is operated by a rocker arm, as shown in Figures 5 and 13. The rocker arm is pivoted on a support, which sometimes en-

closes the inlet valve spring (Fig. 13) and sometimes is separate (Fig. 5.) The rocker

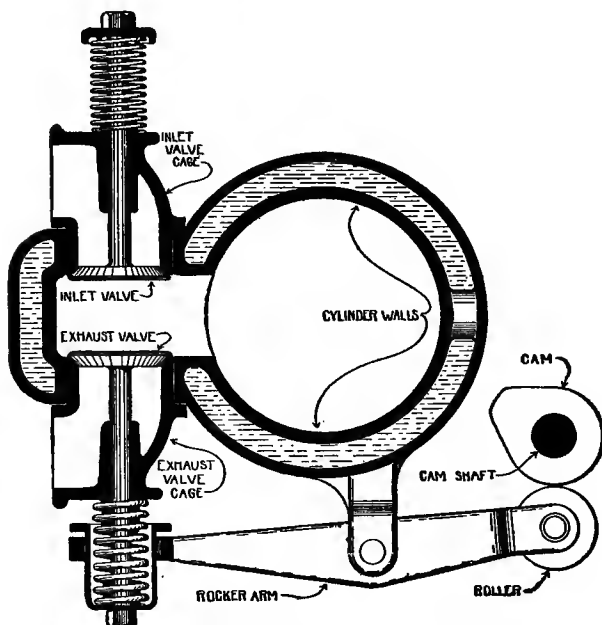


FIG. 16.—VALVE MECHANISM.

arm may be operated by a push rod, or by a cam.

A cam may be described as a wheel with one part bulged out, as shown in Figure 14.

In this illustration the cam is seen acting directly against the end of the valve stem, which is provided with a roller to reduce the friction. The cam is set solidly on a shaft, and revolves with it. The valve is closed when the roller rests on the round part of

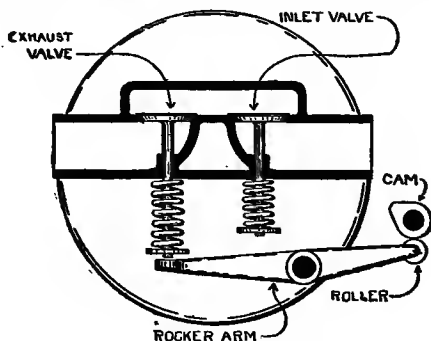


FIG. 17.—VALVE MECHANISM.

the cam. As the cam revolves the bulged part raises the valve stem, and opens the valve; when the bulged part passes from under, the spring brings the valve stem down and closes the valve. The cam may act directly against the valve stem (Fig. 15) or against the rocker arm (Figs. 16, 17, 18), or

against a **push rod** that in turn operates the rocker arm (Fig. 5), or against a push rod that operates the valve stem (Figs. 4 and 19).

The crank shaft makes one revolution to every two strokes of the piston, and therefore the cam cannot be placed on the crank

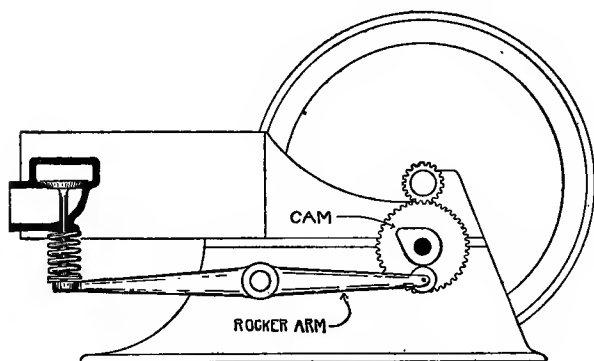


FIG. 18.—VALVE MECHANISM.

shaft, because it would then open the valve too often. The valve must open once during every four strokes of the piston, or once during every two revolutions of the crank shaft, so that the cam must make only one revolution while the crank shaft makes two. This

is done by means of cogs, or **gears**, which are toothed wheels. The gears are so placed that the teeth of one catch in the teeth of the other, or are **in mesh**, to permit one to drive the other without slipping. If the gears have the same number of teeth, 10, for instance, they will run at the same speed, for when one makes a revolution its 10 teeth will have engaged the 10 teeth of the other, and will have forced it to make one revolution also. If one has 10 teeth and the other 20, the 10-tooth gear must revolve twice in order that its 10 teeth may engage the 20 teeth of the other; the 10-tooth gear will, therefore, revolve twice while the 20-tooth gear revolves once.

On a 4-cycle gas engine the crank shaft carries a gear that meshes with a gear twice its size, and the cam is attached to the larger gear, or to the shaft that the larger gear drives. (Figs. 4, 5, 6, and 14 to 19). The cam is thus driven at half of the speed of the crank shaft. The shaft to which the cam is

attached is called the **cam shaft**, or **half-time shaft**, or **side shaft**, or **lay shaft**.

When an engine has been in service the

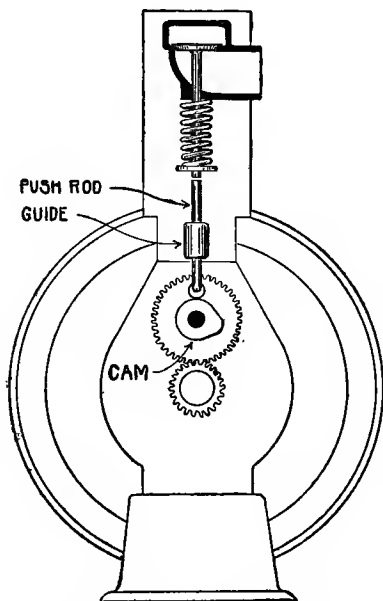


FIG. 19.—VALVE MECHANISM.

valves will have become roughened, and will no longer make a tight fit. This is particularly true of the exhaust valve, because it is

exposed to the intense heat of the gases as they pass out of the cylinder on the exhaust stroke. It should, therefore, be possible to get at the valves in order that they may be refitted. When the valves are in the cylinder head, as shown in Figure 5, it is usually necessary to take off the head in order to get at them. When the valves are as shown in Figure 4, the **valve cap** may be unscrewed, or, as shown in Figure 16, the valves may be in **cages**, which may be unbolted, permitting the valve to be removed complete with its seat and spring.

The fresh gas is led to the inlet valve by the **inlet pipe**, or **inlet manifold**, which is usually short and as straight as possible, for a long or a bent pipe would not permit the gas to flow freely, and would, therefore, reduce the size of the charges drawn into the cylinder.

The exhaust valve connects with the **exhaust pipe**, or **exhaust manifold**, which leads the burned gases away. When the exhaust

valve opens the expanding gases rush out, and if nothing is done to prevent they will make a noise like a gun. The noise is caused by the very sudden expansion that occurs when the gas leaves the exhaust pipe, and if this sudden expansion is prevented the noise will be reduced. Engines are usually provided with mufflers that require the gas to expand gradually, and these consist of several chambers through which the gas must pass in order to escape to the air. As each chamber is larger than the one preceding it, the gas is permitted to expand only a little at a time, so that it finally passes out in a nearly steady and quiet stream instead of in a sudden and noisy puff.

CHAPTER V

CARBURETION

THE first step in running a gas engine is, of course, to supply it with a gas that will burn; the more rapidly and freely the gas burns, the better the engine will run. Small stationary and marine engines run on gasoline or kerosene, which must be turned into gas before they can be used. Furthermore, the gas must be mixed with air before it will burn, for without the oxygen that is in air there can be no fire.

As an experiment to prove that air is necessary in order that there may be fire, pour two spoonfuls of gasoline into a drinking glass, let it stand for a minute or two, and then hold a lighted match to the top of the glass. A flame will at once appear, but it will not

go below the edge of the glass, and there will be a clear and apparently empty space between it and the gasoline. This space is filled with gasoline vapor. The upper surface of this body of gas is in contact with the surrounding air, and combustion will take place only where the two become mixed. As a further test, attach a lighted match to a wire, and dip it into the glass; it will go out as soon as it has passed through the flame and into the gasoline vapor. It is obvious that due precautions should be taken in trying these experiments, and that it is better to try them out-of-doors than in the house.

It is quite as important to supply an engine with air as with gasoline; as a matter of fact, the quantity of gas necessary is very small in comparison with the quantity of air that the engine requires. For example, an engine delivering one horse-power will consume less than one pint in an hour. Running at 500 revolutions per minute, it will make 15,000 inlet strokes in an hour, during each of which

it will take in a charge of gas and air. As the pint is therefore divided into 15,000 parts, it can be seen that the single part required for each inlet stroke is not more than a drop or two.

A gas and a liquid will not mix; in order to mix gasoline with air it must be **vaporized**, or turned into gas. The chief reason for the general use of gasoline in engines is the ease with which it vaporizes at ordinary temperatures. Kerosene, alcohol, distillate, and the heavier oils must be heated in order to vaporize, and engines using them are so designed that they are heated to the proper point.

Gasoline will vaporize if it is poured into a saucer, and in the course of time it will disappear. If the same quantity is splashed out of the saucer, and caught by the wind, it will disappear very rapidly. In the first case only the upper surface is exposed to the air, but in the second case it is broken up into drops, and as each of the drops is exposed to

the air, it vaporizes all over. A gas engine runs so rapidly that very little time is allowed for the formation of the mixture; the gasoline is therefore formed into spray in order that it may vaporize as quickly as possible.

Attached to the inlet pipe of the engine is a device that proportions the gasoline and air, and supplies the mixture on which the engine runs. This is so arranged that the air drawn into the cylinder during the inlet stroke must pass through it, and it sprays into this current of air the necessary quantity of gasoline. The gasoline is carried along by the air, being vaporized and mixed with it by the time that the compression stroke is ended.

Air that is mixed with a combustible gas is said to be **carbureted**; the apparatus by which the air is carbureted is called a **carbureter**, some forms of carbureters also being known as **vaporizers** and **mixing valves**, or **mixers**.

The principle of the mixing valve is shown in Figure 20, which illustrates part of a cylinder, with the mixing valve attached to the inlet pipe. The part called the **air valve** is of the same form as an exhaust valve or an inlet valve, and is made of brass; in the sketch it is shown as being held on its seat by its own weight. A fine hole is drilled in the seat in such a position that when the air valve is on its seat it closes the hole. This hole, which is called the **jet**, is connected to the gasoline supply. When the air valve is on its seat, as shown in the first sketch, it prevents the gasoline from flowing, and this will be the situation during the compression, power, and exhaust strokes. The air that is drawn into the cylinder during the inlet stroke must lift the air valve from its seat in order to pass, however; the gasoline that flows out of the jet when the valve moves is picked up by the air and carried to the cylinder.

The quantity of gasoline flowing out of the

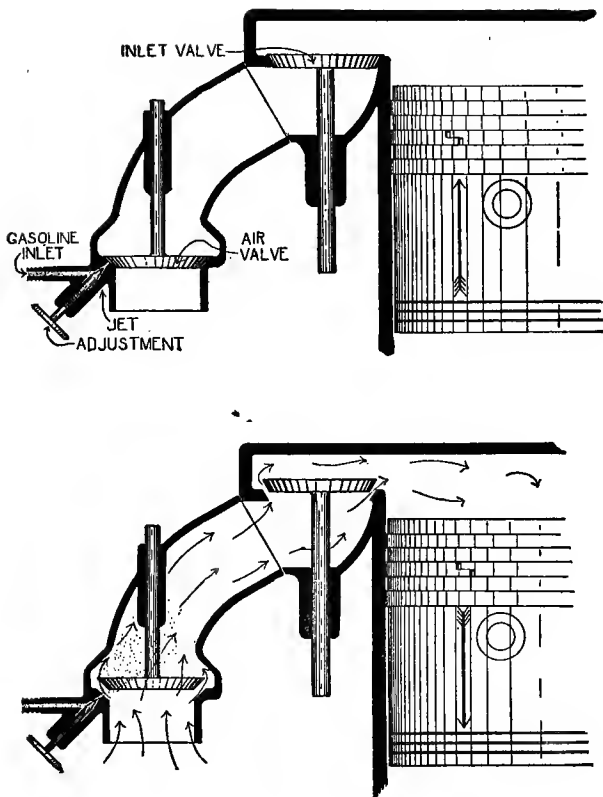


FIG. 20.—PRINCIPLE OF MIXING VALVE.

jet is adjusted by a **needle valve**, which is a pointed screw fitting into the jet opening. By screwing the needle valve in or out the passage to the jet may be made smaller or larger, which permits the flow of gasoline to

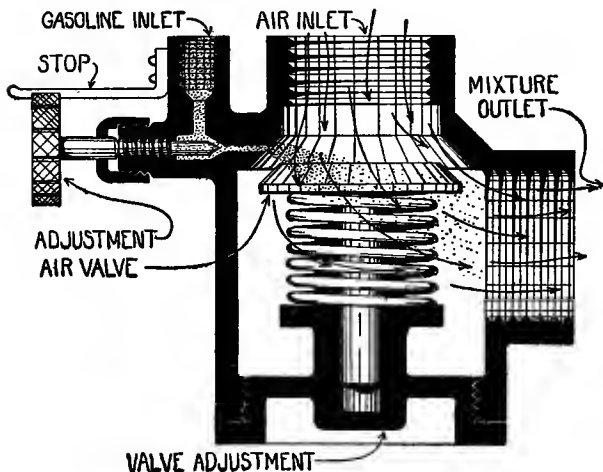


FIG. 21.—MIXING VALVE.

be adjusted to the air flowing through the inlet pipe.

In the mixing valve shown in Figure 21 the air valve is held to its seat by a spring, the strength of which may be regulated by

screwing the lower portion of the case. The needle valve is provided with a **stop spring** that catches in grooves cut in the head, and

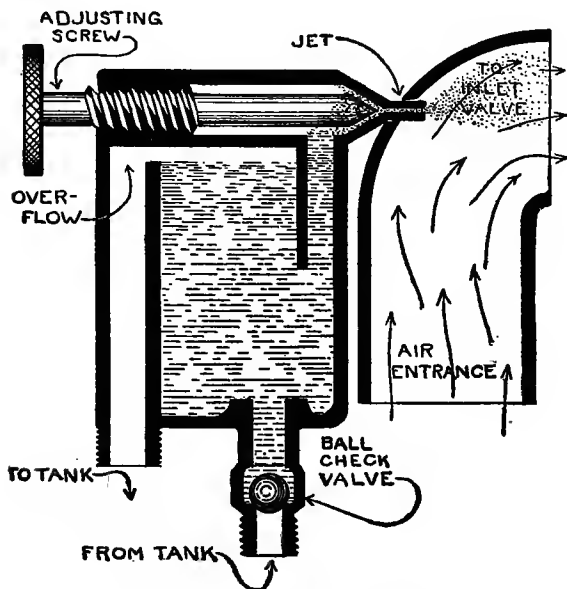


FIG. 22.—OVERFLOW VAPORIZER.

prevents it from moving when once it has been adjusted.

Figure 22 illustrates a vaporizer in which

the gasoline is sucked out of the jet instead of flowing out by gravity. It has a small chamber, in which the gasoline is prevented from rising above a certain level by an **overflow** that drains off the surplus and conducts it back to the supply tank. The chamber is kept filled by a pump driven by the engine; the **ball check valve** lifts from its seat to permit gasoline to enter, but when the pump completes a forcing stroke the ball returns to its seat and prevents the gasoline from flowing back. The jet is somewhat higher than the level of the gasoline, but the suction in the air passage during an inlet stroke is sufficient to suck out the gasoline.

The vaporizer shown in Figure 23 is similar in principle, but in place of the jet it has what is called a spray nozzle. The spray nozzle is a small pipe that projects into the air passage, and with its end bent up so that the tip is slightly higher than the level of the gasoline in the chamber with which it is connected. The flow of air through the air pas-

sage sucks the gasoline out of the spray nozzle.

Figure 24 shows a spray nozzle vaporizer

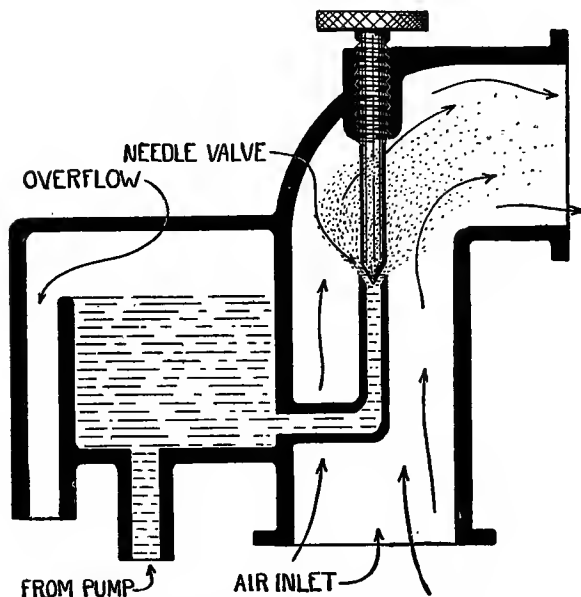


FIG. 23.—SPRAY NOZZLE VAPORIZER.

in which the gasoline level is maintained, not by an overflow, but by a float. The gasoline chamber, or float chamber, contains a block of cork or a tight metal box, to which is at-

tached a pointed rod shaped to fit the gasoline inlet. When gasoline flows into the float chamber the float will rise on it until the pointed rod, or float valve, is high enough to close the opening and shut off the flow. This is shown in the first sketch, in which the inlet valve is closed and no suction exists in the inlet pipe. During an inlet stroke gasoline will be sucked out of the float chamber by way of the spray nozzle; the float drops in consequence, and the opening of the float valve permits more gasoline to enter the float chamber. This is shown in the second sketch.

While no adjustments are shown in Figures 23 and 24, a needle valve is always provided, for it is essential to keep the flow of gasoline in proper proportion to the flow of air.

These carbureting devices are simple, for the engines on which they are used run at fixed speeds, and with uniform suction. Mixing valves and vaporizers are useless on engines that run at changing speeds, as is the

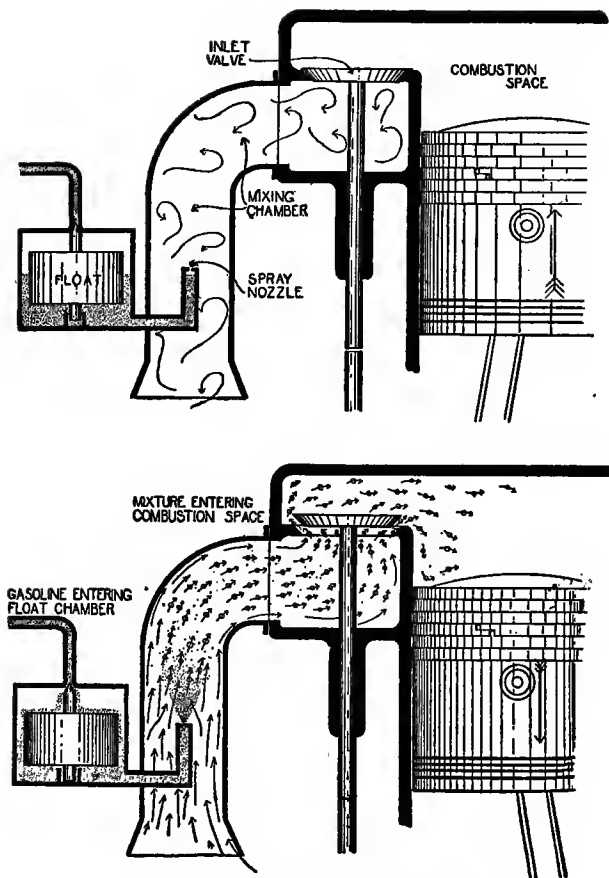


FIG. 24.—PRINCIPLE OF FLOAT FEED.

case with automobile engines and also with some stationary engines, for they do not allow for the change in suction that occurs with every change in speed. When an engine speeds up the suction increases, and more air is drawn through the inlet pipe, and more gasoline is sucked out of the jet or the spray nozzle, than is the case at low speed. If the air and the gasoline remained in proportion no harm would be done, but this is not the case, because the flow of gasoline increases faster than the flow of air. If this condition is not corrected the mixture becomes **too rich**.

If the gasoline adjustment is changed to give a correct mixture at high speed, the decrease in suction when the engine is slowed down will reduce the flow. Too little gasoline will be drawn out of the jet at low speed, making the mixture **poor or lean**, and another adjustment will be necessary. An engine running at varying speeds is therefore fitted with a **compensating carbureter** that provides a

uniform mixture, and overcomes the difficulty by changing the adjustments automatically.

The principle of a compensating carbureter is illustrated in Figure 25, which also shows a **throttle** for the control of the engine speed.

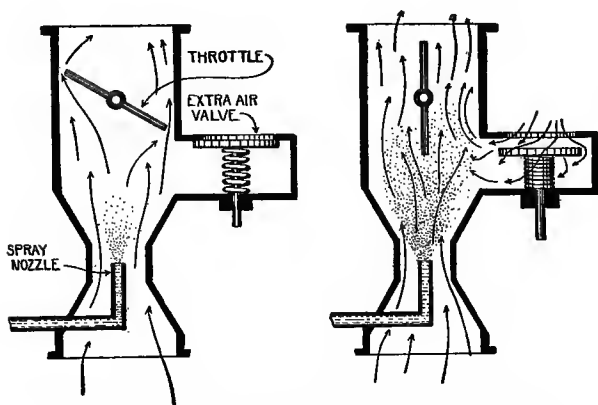


FIG. 25.—PRINCIPLE OF COMPENSATING CARBURETER.

This throttle is similar in every way to a damper in a stove-pipe; it is a disk that may be turned to close the inlet pipe and reduce the quantity of mixture flowing to the cylinder, as shown in the first sketch, or that may be turned edgewise to open the pipe, as

shown in the second. On the side of the carbureter will be seen an opening, against which a leather or metal disk is pressed by a spring. This is the **extra air valve** that compensates for the increased flow of gasoline at high speed.

When the throttle is closed, or nearly so, the suction is weak and the flow of gasoline is adjusted to the small quantity of air then passing. When the throttle is opened a greater quantity of mixture passes to the engine, which speeds up and greatly increases the suction in the air passage. The suction becomes great enough to draw the disk back from the opening, and a sufficient quantity of air enters to compensate for the extra quantity of gasoline flowing out of the spray nozzle. This is indicated in the second sketch. When the engine slows down and the suction is reduced, the spring forces the disk against the opening. Every change in engine speed is accompanied by the opening or closing of the air valve, and by changes in the quantity

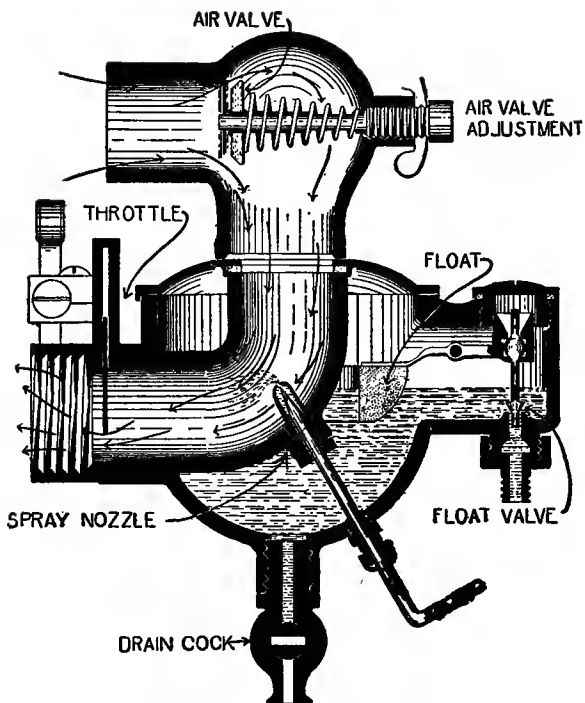


FIG. 26.—COMPENSATING CARBURETER.

of air to compensate for changes in the flow of gasoline.

Figure 26 shows a float feed compensating carbureter, in which the air passage passes through the float chamber instead of being on one side of it. This requires the float to be in the shape of a horseshoe instead of being a block. As the gasoline enters the float chamber at the bottom instead of at the top, the float is pivoted so that when it drops the float valve is lifted from its seat. There is only one opening for the air, the size of which may be changed to admit a greater or less quantity. The extra air valve is a leather disk that may slide on its stem, with a spring pressing it against its seat. The seat is so made that an opening is left even when the valve is closed, and enough air may pass through this opening to permit the engine to run slowly. When the engine speeds up the suction slides the air valve back from its seat, permitting the required extra air to enter. The illustration shows the valve in

this position; it also shows the throttle that may slide across the air passage to reduce the flow of mixture. Gasoline flows from the float

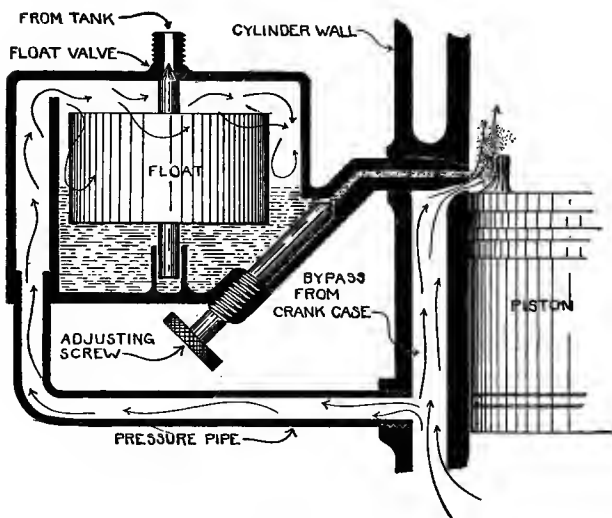


FIG. 27.—PRESSURE VAPORIZER, OR INJECTOR.

chamber to the spray nozzle by the passage around the needle valve.

In these types of carbureter the gasoline is drawn out of the jet or the spray nozzle by suction, but Figure 27 shows one in which the

gasoline is forced out by pressure. The gasoline level is maintained by a float, and the jet is adjusted by a needle valve, these being similar to the ones already described. The difference is in the float chamber, which is air-tight in order to prevent the leakage of the pressure.

This **pressure vaporizer**, or **injector**, is used on 2-cycle engines, the pressure being obtained from the crank case. During the outward stroke of the piston compression is produced in the crank case, and is communicated to the float chamber by the **pressure pipe**. At the end of the stroke, when the piston has uncovered the inlet port, the pressure is sufficient to force the liquid out of the jet, and it passes into the cylinder. An injector of this kind permits the use of kerosene. In order to vaporize kerosene it must be heated; this is done by spraying it against the **baffle** or **deflector** on the piston, which is kept hot by the burning mixture. Figure 28 shows a 2-cycle engine with the injector attached.

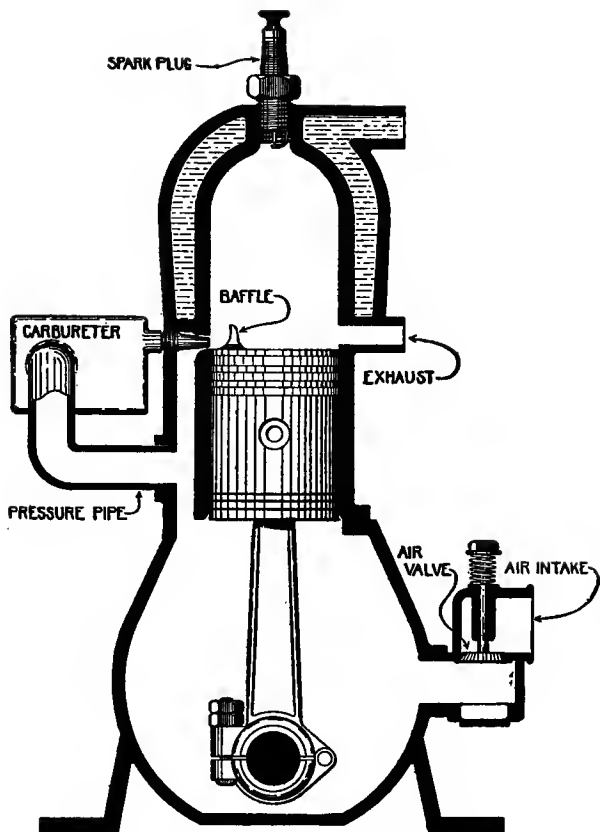


FIG. 28.—INJECTOR ON 2-CYCLE ENGINE.

Still another method of forming the mixture is by means of a **fuel valve**, which is operated by a cam exactly as the exhaust valve is operated. The fuel valve is located in the inlet pipe close to the inlet valve, the arrange-

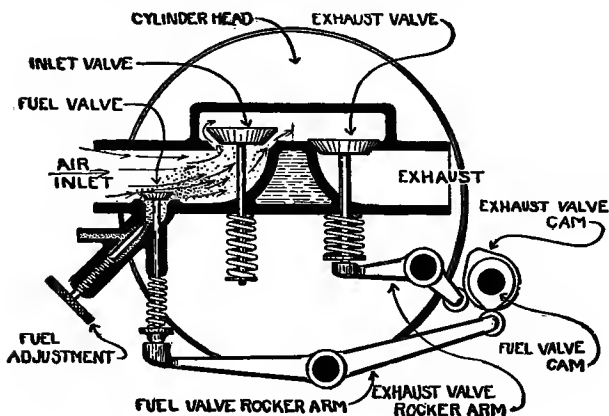


FIG. 29.—VALVE CARBURETER.

ment being shown in Figure 29. It is held open by the cam during the inlet stroke, to permit the gasoline to be drawn up by the suction.

The carbureter must be constantly supplied with gasoline, and the simplest way to do this

is to elevate the supply tank so that the gasoline will flow by gravity. With such an arrangement, however, there will be the constant danger of fire or explosion from a leaking joint; the fire underwriters therefore prohibit this method of feeding, and require the supply tank to be below the carbureter. This makes it necessary to raise the gasoline. If the tank is close to the carbureter the suction during the inlet stroke will be sufficient, and this method is used on many small engines. It is more usual, however, to fit the engine with a pump.

The principle of a gasoline pump is shown in Figure 30. A pump consists of a cylinder that is bolted to the engine, and a plunger that is driven by a cam, a crank, or an eccentric. Two check valves are provided, one to prevent the gasoline from flowing back to the supply tank from the pump cylinder, and the other to prevent it from flowing back to the pump cylinder from the carbureter. The first sketch shows the plunger moving upward, on

a suction stroke, and drawing gasoline into the pump cylinder from the supply tank; this movement holds one check valve on its seat, but lifts the other. The second sketch shows the plunger moving downward on a forcing stroke, and driving the gasoline from the pump cylinder to the carbureter.

Figure 30 shows a very usual method of driving the gasoline pump, consisting of a cam to force the plunger downward and a spring to raise it when the cam ceases to act. When the cam projection is up, as shown in the second sketch, the plunger may be worked by hand to fill the carbureter; this will be necessary if the engine has been idle for some time. In other cases the plunger is driven by a link or a connecting bar, so that it is pulled upward instead of being lifted by a spring.

Gasoline is so dangerous that it is necessary to prevent leakage, and gasoline pumps should always be so made that there can be no leakage between the plunger and cylinder walls. Figure 31 shows two ways in which

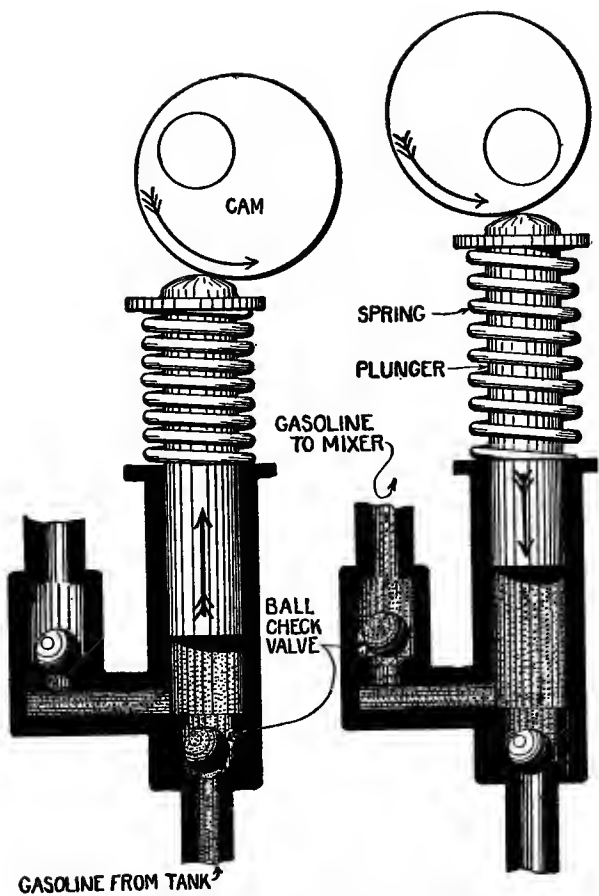


FIG. 30.—PRINCIPLE OF GASOLINE PUMP.

this can be done. As shown in the first sketch, the upper part of the pump cylinder is sometimes made with a channel surrounding the plunger; any gasoline finding its way be-

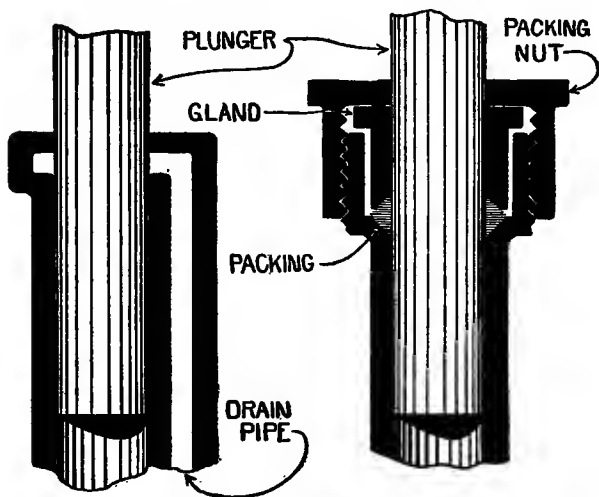


FIG. 31.—METHODS OF PREVENTING LEAKAGE.

tween the plunger and cylinder walls will be caught by this channel, and will flow back to the supply tank by the drain pipe.

The second sketch shows a stuffing box. The upper part of the pump cylinder is

threaded for a packing nut, which, when it is screwed down, presses against a metal gland that surrounds the plunger. Between the bottom of the gland and the cylinder is a packing of lamp wicking, leather, or other soft material, which is pressed against the plunger by the shape of the parts that support it. When the packing nut is screwed down the packing is forced against the plunger, and makes a joint that prevents leakage, but that does not offer enough friction to cause the plunger to bind.

CHAPTER VI

IGNITION AND ELECTRICAL PRINCIPLES

THE charge of mixture having been taken into the cylinder, the next step in the cycle is to set it on fire, or, in other words, to ignite it. The setting on fire, or **ignition**, of the mixture is of great importance, for if it is not done correctly the engine will lose power.

Each charge of mixture will produce a definite quantity of heat when it is burned, the heat in turn being capable of producing a definite pressure. If the engine is to run efficiently, and is to develop its full power, the greatest possible proportion of this pressure should be utilized in driving the piston outward on the power stroke. If the ignition of the mixture is not correct much of the heat

will be wasted, and only a small part will be left for producing pressure and power.

The defective action of any of the engine parts will result in a waste of power, but a greater waste of power will be due to defective ignition than will be caused by anything else.

If the heat from the entire charge of mixture could be produced at the instant when the piston is at the end of the compression stroke and beginning to move outward on the power stroke, the engine would deliver the greatest possible power. This would make it necessary to set fire to all of the particles of mixture at the same time, so that the entire charge would burst into flame. There is no way to do this, however; the ignition systems in use set fire to a few of the particles of mixture and require the flame to spread from these throughout the rest of the charge.

The mixture burns very rapidly, and at first it would seem as if the time required for the spreading of the flame was so small that

no attention need be paid to it. It must be remembered, however, that the piston moves at very high speed; if the engine is running at 450 revolutions per minute, for instance, the piston will make 15 strokes per second. If the mixture is set on fire when the piston is at the end of the compression stroke the piston will be moving outward on the power stroke while the flame is spreading, and will be quarter or half way through the stroke by the time that all of the charge is on fire. The pressure produced against the piston will then be quite small, because the space in which it is produced is large.

If, on the other hand, the mixture is set on fire while the piston is making the compression stroke, and before it reaches the top, the piston will be moving inward while the flame is spreading, and will be at the beginning of the power stroke at the instant when all of the mixture is burning. The pressure against the piston will then be great because the space in which it is produced is small.

No matter whether the engine is running fast or slow the time required for the spread of the flame does not change, and it must be allowed for. When an engine speeds up the piston moves faster, and the mixture must be set on fire correspondingly earlier in the stroke in order that all of it may be burning when the piston begins the power stroke. This is called **advancing the ignition**. If the engine is slowed down without changing the time of ignition the mixture will all be on fire before the piston has had time to get to the end of the stroke; the piston must then move against the great pressure, and will be slowed down or even stopped.

When the engine speed changes the ignition point should be changed to correspond. It should thus be early in the compression stroke, or **advanced**, for high speed, and late in the compression stroke, or **retarded**, for slow speed.

The apparatus that ignites the mixture should work with the greatest possible reli-

ability, and should be under absolute control. Long experience has shown electric ignition to have the greatest reliability, and this is universally used on small stationary engines. At the instant when an ignition spark is required the electric ignition system produces an electric spark in the cylinder, which sets fire to the particles of mixture that it touches, and starts a flame that spreads through the entire charge.

An electric ignition system consists of a generator for producing an electric current, a device for controlling the instant at which the spark occurs, and a device inside of the cylinder at which the spark is formed. If the ignition is wrong everything is wrong, and in order to keep it in good working order the engine user must know the operation of the spark-producing apparatus. This requires a slight knowledge of electricity, and it may be said at once that while electricity is a most mysterious force there is no difficulty in understanding how it may be produced

and controlled, and how it may be made to do work.

Electricity is considered to exist in everything, but it is not noticed as long as it is at rest. In order to make electricity useful it must be started in motion, or converted into an **electric current**; an electric current is moving electricity, just as a river is moving water, or as wind is moving air. A generator is a device that starts electricity in motion and produces an electric current; the battery that rings the front door bell is a generator, and so is the dynamo that lights the electric lamps.

In order to move anything, whether it is a wheelbarrow, a house, or electricity, it is necessary to exert pressure; thus a pump makes water move by exerting pressure against it. Steam flows out of a boiler because there is greater pressure inside of the boiler than there is outside, and the steam flows from where the pressure is high to where the pressure is low.

Figure 32 shows a pump drawing water out of a tank and forcing it through a pipe; the water flowing out of the end of the pipe strikes a water wheel and makes it turn. The pump starts the water in motion, and as long as the pump runs the water is made to flow

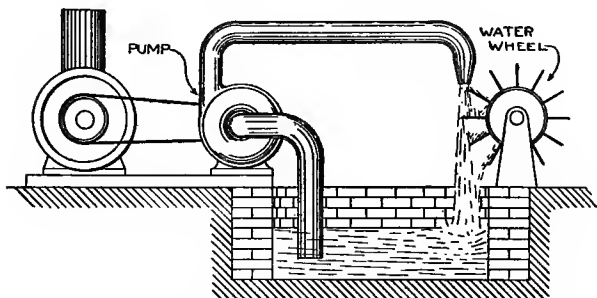


FIG. 32.—PRINCIPLE OF FLOW OF ELECTRIC CURRENT.

to it from the tank, and through the pipe, making the water wheel run in returning to the tank. The pressure produced by the pump makes the water flow, and the moving water does work in driving the water wheel. In a similar manner a steam engine is made to run by being put in the path of steam that is flowing out of a boiler.

This also represents the action of an electric current. Instead of the pump or the boiler there is an electric generator to start the electricity in motion by producing pressure. The flow of water is guided by a pipe, whereas the flow of electricity is usually guided by a copper wire. The current of electricity is expected to do work in ringing a bell, or in lighting a lamp, or in producing an ignition spark, and the wire, therefore, leads the current to the bell, or to the lamp, or to the sparking apparatus.

If the water did not flow back to the tank after making the water wheel turn the tank would go dry and the flow would stop. Similarly, the electric current must return to the generator after doing its work. To make use of an electric current it must be given a complete path, or **circuit**, as it is called; if the current is to operate some kind of apparatus it is only necessary to put the apparatus in the circuit so that the current must flow

through it in order to return to the generator. (Fig. 33.)

Every pump has an intake and an outlet, the pressure being higher at the outlet than at the intake. If one of these openings is stopped up the flow will cease. An electric generator also has an intake and an outlet called **terminals**. The pressure is high at the

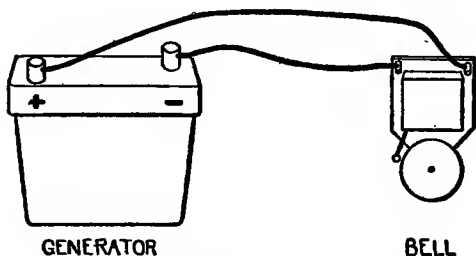


FIG. 33.—ELECTRIC CIRCUIT.

outlet, and the current flows from there through the circuit to the intake, where the pressure is low. The electrical man speaks of the outlet as the **positive**, or **plus** (+), terminal, and of the intake as the **negative**, or **minus** (—), terminal. These terms and signs

indicate the direction in which the current flows.

As it always costs something to produce an electric current, the circuit should be so made that the current cannot leak back to the generator without doing the work expected of it. Suppose that the pipe in Figure 32 is leaky, and that half of the water leaks back to the tank without going to the water wheel; then, if it costs 10 cents an hour to drive the pump, 5 cents an hour will be wasted because only half of the water is doing the work of driving the water wheel.

An electric current will flow over all kinds of metal, but will not flow over rubber, or cotton, or china, or mica, or wood; metals are **conductors** of an electric current, while the other substances are **non-conductors**, or **insulators**. The current can be prevented from leaking by covering the wire with rubber or cotton, and **insulated wire** is always used.

The path or circuit provided for the cur-

rent may be of wire, or it may be made up of different pieces of metal. The pieces of metal must touch, however, or be **in contact**; if they do not touch, so that there is an air space between them, the current cannot flow, for air is one of the best insulators. When the circuit is interrupted by an air space it is said to be an **open circuit**; when the metal path is complete, and the current can flow, the circuit is said to be **closed**.

In an ignition system the current flows part of the way by wire, and part of the way by the metal of the engine. This is called a **grounded circuit**, to distinguish it from a **metallic circuit**, which is composed entirely of wire.

When a man buys a pump he tells the dealer that he wants it to lift water to a tank so many feet higher than the well, which means that he expects the pump to produce enough pressure to lift the water the required distance. An electric generator is bought in the same way, for it must produce enough

pressure to force the current through the circuit.

The pressure of a stream of water is measured in pounds per square foot, while the measure of electric pressure is the **volt**. The electric pressure required by the usual ignition system is 6 volts; in other words, the apparatus is so made that a pressure of 6 volts is required in order to force through it a sufficient quantity of electricity to make it work. If the pressure is too low, the apparatus will not work; if the pressure is too great, the apparatus may be injured by the excessive quantity of electricity that will be forced through it.

If a pump is pumping hot water the pipe will become heated, and so will the air surrounding the pipe. The flow of water thus has a direct effect on the air around the pipe. Similarly, the flow of an electric current over a wire has a direct effect on the air surrounding the wire; the space around the wire becomes charged with that mysterious force

known as magnetism. This force appears on the instant that the current begins to flow, and dies away when the current stops flowing.

At first thought magnetism would not seem to have anything to do with an ignition spark, but as a matter of fact it has everything to do with it, for the ignition spark is always produced by magnetism. A battery, for instance, will not give a proper spark; the battery current is therefore used to produce magnetism, and the magnetism is used to produce another current, from which a proper spark may be obtained. In order to understand an ignition system there must therefore be some understanding of magnetism and of how it may be produced and used.

Everyone has played with a magnet, and knows that it will pick up pieces of iron and steel, but that it has no effect on wood, copper, rubber, or any other substances. When iron filings are stirred with a copper wire they will not be attracted to it, unless an elec-

tric current is flowing through the wire, when the filings will cling to it as if it were a true steel magnet. (Fig. 34.) The filings will jump to the wire and cling to it the instant that the current begins to flow, but will fall away when the flow of current stops.

Iron filings will not be attracted to a piece

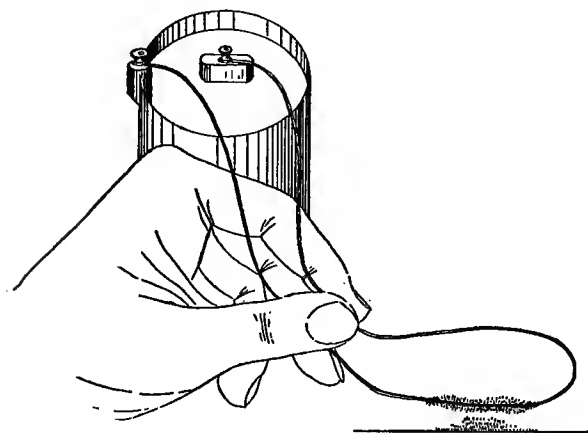


FIG. 34.—MAGNETISM PRODUCED BY A CURRENT.

of iron, but if a magnet is brought near the piece of iron the filings will be attracted, and will thus show that the iron is then a magnet.

(Fig. 35.) When a piece of iron is brought near magnetism it becomes a magnet, and remains a magnet until the magnetism is removed.

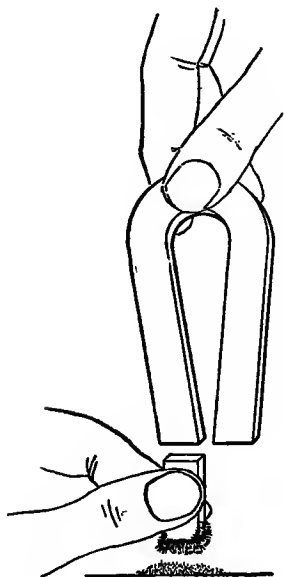


FIG. 35.—MAGNETIZING A
PIECE OF IRON.

Two facts are thus established, one being that the flow of current over a wire produces magnetism, and the other that iron will be a magnet as long as it is near magnetism. Bearing these in mind, wind a piece of wire around a bar of iron and pass a current through it; the bar will become a magnet and will remain so

while the flow of current continues. (Fig. 36.) The wire used for this experiment should be insulated to prevent the current from leaking to the iron, as otherwise it will

not do the work of magnetizing the bar that it is expected to do.

Now let us take a 20-foot piece of wire, and attach one end to a terminal of a generator; a battery, for instance. The current will flow through the wire when the other end is

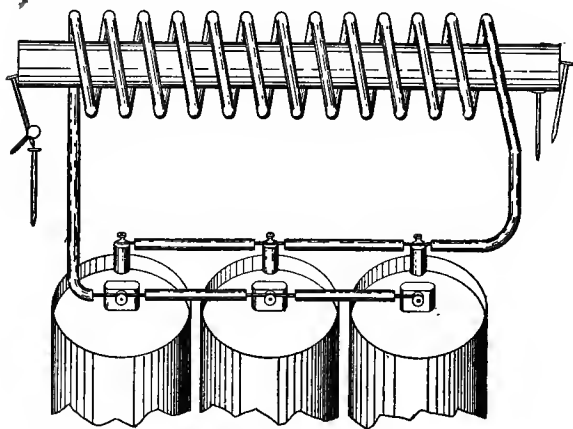


FIG. 36.—MAGNETIZING AN IRON BAR BY ELECTRICITY.

touched to the remaining terminal of the generator, and when the circuit is broken by separating the wire from the terminal a small spark will be seen. This is produced by the current in trying to continue to flow. If the

wire is wound around a bar of iron and the same experiment is tried the spark that will appear when the circuit is broken will be seen to be much larger. As the battery and the wire are the same, the larger spark that is produced when the wire is wound around the bar can only be due to the magnetizing of the bar by the flow of current in the wire.

It can thus be seen that an electric current may be obtained from magnetism, just as magnetism may be obtained from an electric current. There is one difference, however, and it is an important one. An electric current produces magnetism for as long as it flows, but magnetism produces an electric current only when the magnetism is changing strength, or, in other words, when it becomes stronger or weaker.

A bar of iron has no magnetism, but becomes magnetized when a magnet is brought near it. If a wire is wound around the bar a current will flow in it while the bar is becoming magnetized. When the bar becomes

fully magnetized the current will stop flowing. Then when the magnet is removed the magnetism of the bar will die away, and while it is dying away another current will flow in the wire.

If the magnetism gains strength or dies away slowly the current will be weak; to produce an intense current, therefore, the magnetism should be made to change its strength as suddenly as possible.

CHAPTER VII

ELECTRIC GENERATORS

AN engine can be made to run on a poor mixture, or with loose bearings or weak compression, but it will refuse to run if the ignition is defective. Of the various parts of the engine the ignition is the most important, for any defect in it will immediately cause the engine to lose power or to stop. It is of the utmost importance to supply the engine with an unfailing electric current, and the most reliable electric generator is a **magneto**.

A magneto produces current by the revolving of a coil of wire in the magnetism of permanent steel magnets. The wire is wound on an iron **core**, which is shaped as shown in Figure 37, with an enlarged part or **head** on each end. In the sketch the wire is indicated

by the heavy black line; on a complete **armature**, which is the name given to the revolving part of the magneto, the wire fills the space between the heads. The magnets are bent in the form of the letter U and, as is the case with all magnets, the magnetism flows through them in a continuous circuit from

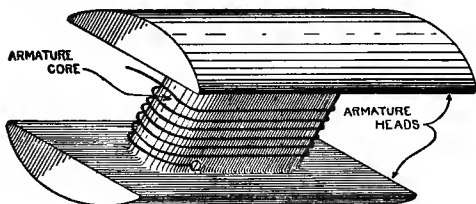


FIG. 37.—MAGNETO ARMATURE.

one end to the other, and across the space between their ends. The armature is placed between the ends, where the magnetism is strongest, and as magnetism flows through iron far more easily than through air, the iron core and heads form a bridge by which it may pass from one end of the magnet to the other.

In some positions of the armature the easi-

est path for the magnetism will be through the core, while in others the flow will be through the heads. In A, Figure 38, the flow of magnetism is through the core, because that is the easiest path for it to take. When the armature moves to position B most of the

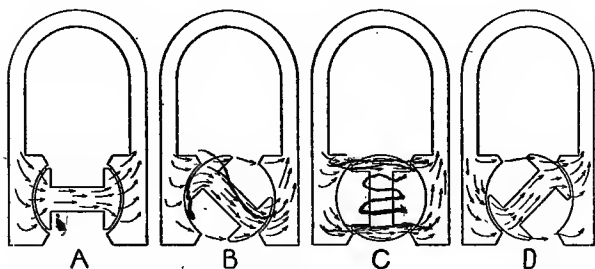


FIG. 38.—MAGNETISM FLOWING IN THE ARMATURE CORE.

magnetism still flows through the core, the rest finding it easier to jump across the air space between the edges of the heads and the pieces of iron called **pole shoes** attached to the magnets. When the armature moves to position C all of the magnetism flows across by the heads, for that is now the easiest path.

In positions A and B the core is mag-

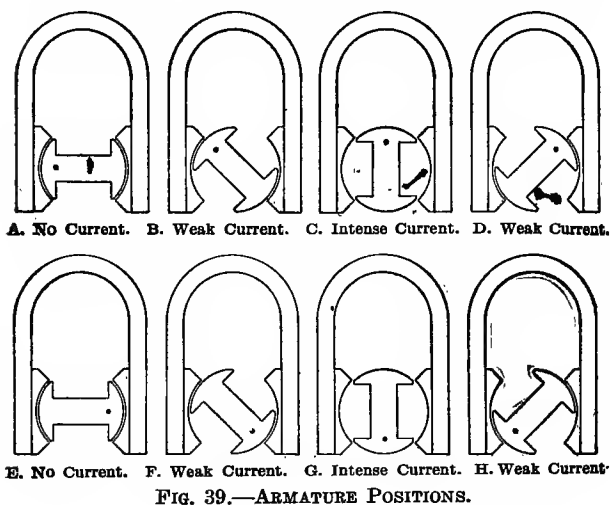
netized by the flow of magnetism through it. In position C the core loses its magnetism, and it is the dying away of the magnetism of the core that produces an electric current in the winding.

As the armature passes from A to B, and from there toward C, less and less of the magnetism will flow through the core, and this change in the magnetizing of the core will produce current in the winding. This current will be small, because the magnetism of the core will be changing strength slowly. The current will not be intense enough to use for ignition until the great change in the strength of the magnetism occurs, which will be as the armature passes over position C.

This complete dying away of the magnetism of the core will occur twice during each revolution, and each time that it occurs a current sufficient for an ignition spark will be produced in the winding. (Fig. 39.)

A magneto thus gives a current only at certain points in the revolution of the arma-

ture, and it is clear that it should be so driven that it is giving its current at those times when the engine requires a spark. A magneto of this kind must have a **positive drive**;



that is, it must be so driven that when the piston reaches the firing position the magneto is in a sparking position. When the magneto is once set so that it gives a spark when the engine needs one, it must be kept in that relation, for if it slips it will no longer

give its spark at the correct time. Magnetos are usually driven by gears, just as the cam shaft is driven, for in that manner slipping is prevented.

For a 1-cylinder, 4-cycle engine the magneto may be driven so that it is in position C, Figure 39, and giving a spark, when the piston is in the firing position. To obtain a second spark the armature must make a half-revolution to position G. The crank shaft of the engine must make two revolutions before another spark is required, however, so that the armature would be revolving at one-quarter the speed of the crank shaft. It is far more usual to drive the armature at one-half of the speed of the crank shaft, the armature making one revolution while the crank shaft makes two, and to make use of only one of the two sparks per revolution that the magneto is capable of producing.

It has been said that the more suddenly the magnetism changes strength the more intense the current will be. When the arma-

ture is turned very slowly the magnetism of the core will change strength, but the change will be so gradual that the current may not be able to form a spark. As the speed increases the changes will take place faster and faster, and the current will become more intense. When the magneto is driven at one-quarter the speed of the crank shaft it might be difficult to crank the engine fast enough to get a starting spark from the magneto, but with a good magneto driven at one-half the crank shaft speed a small stationary engine may be started easily and with little effort.

When once started the magneto will continue to give ignition sparks indefinitely, with no more attention than an occasional oiling.

Some engines have such weight and compression that they cannot be cranked fast enough to obtain an ignition spark from a revolving magneto, and as such engines do not run at a higher speed than 500 revolutions per minute they are fitted with **oscillating magnetos**. In an oscillating magneto the

armature is not revolved by gears, but is held in position C, Figure 38, by springs, which are attached to a trip lever secured to the armature shaft. A cam or arm driven by the engine presses the trip lever to one side, thus turning the armature to position B or F, and stretching the springs. At the instant when

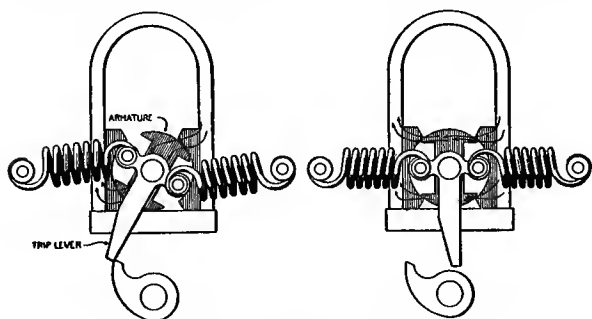


FIG. 40.—OSCILLATING MAGNETO.

ignition is desired the trip lever is released, and the springs snap the armature back to position C, which causes a change in magnetism, and produces a spark exactly as if the armature were revolving. (Fig. 40.)

No matter how slowly the armature may be moved by the engine the speed with which

the springs move it will be sufficient to produce a most intense ignition spark.

Gear driven and oscillating magnetos are made in various forms, according to the ignition systems for which they will be used, and give the greatest possible reliability and efficiency.

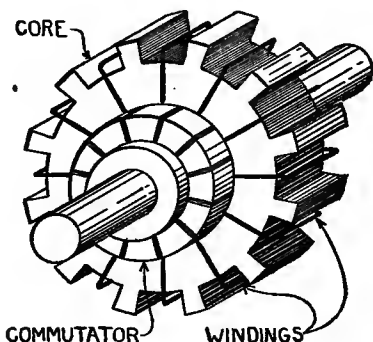


FIG. 41.—ARMATURE OF FRICTION-DRIVE GENERATOR.

In a type of generator that is in frequent use the current is produced under the same principle as a magneto, but the application of the principle is somewhat different. Instead of a single winding on the armature there are a number of windings, as indicated

in Figure 41. The ends of these windings are attached to blocks of copper insulated from one another, and which form the **commutator**.

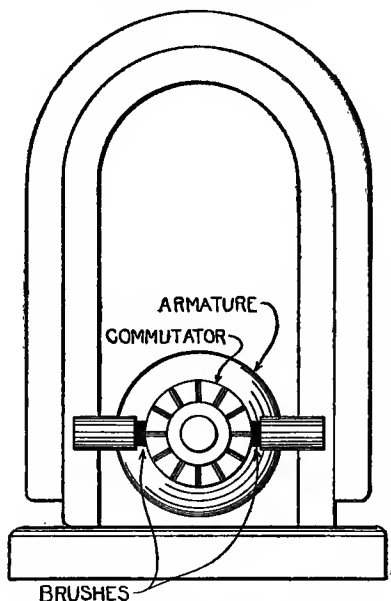


FIG. 42.—FRICTION-DRIVE GENERATOR.

These windings are acted on successively by the magnetism, so that current is produced in them one at a time. The current flows to the commutator and then to blocks

of carbon, called **brushes**, that are pressed against the commutator by springs. (Fig. 42.) These brushes form the terminals, and are connected to the circuit.

If the length of all of the windings taken together is the same as the length of the single winding of the magneto, and if the magnets are of equal strength, the generator and the magneto will give equal currents. Instead of the generator current being concentrated at two points in the revolution, as is the case with the magneto, it will be spread out, so to speak, over the entire revolution, and will not, of course, be so intense. In order that these generators may produce a sufficiently intense current for ignition they must be run at very high speed, and they are driven either by belt or by friction. This gives them their name of **friction-drive generators**.

The shaft of a friction-drive generator is usually fitted with a leather wheel, which is pressed against the flywheel of the engine

and is thus driven. The speed at which it is run may be 2,000 revolutions per minute or more. The leather friction wheel may press against the face or side of the flywheel, or a bevelled edge. (Fig. 43.)

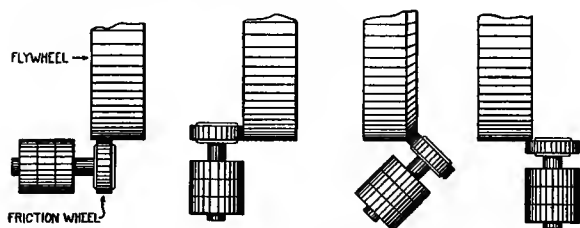


FIG. 43.—LOCATIONS OF FRICTION-DRIVE GENERATORS.

A magneto produces its intense current at intervals, and, as has been explained, it is so set that this intense current is used in producing a spark. On the other hand, a friction-drive generator produces electricity all of the time that it runs, but the electric current is only permitted to flow when a spark is required. The electricity that is produced at other times endeavors to flow, but cannot do so because no circuit is provided for it. If it becomes sufficiently intense it will make a

circuit for itself by burning the insulation of the windings, which will ruin the generator.

In order to prevent the generator from running at so high a speed that the intense current will burn out the armature the friction wheel is provided with a governor that pulls the friction wheel away from the fly-wheel, or else lets the armature run free. When the speed of the armature is sufficiently reduced the governor again permits it to be driven.

Some friction drive generators obtain their magnetism from permanent steel magnets, as magnetos do, while others obtain it from their own electric currents. It has been explained that when a current flows through a wire wound around an iron bar the bar becomes magnetized; Figure 44 shows how this principle is applied to a generator. The armature revolves between the ends of two iron bars, or cores, the other ends of which are connected by another bar of iron. The cores are wound with wire, as indicated in the

sketch, one end of the winding being connected to one of the brushes, while the other goes to the circuit. The cores are hard enough to retain a little magnetism, so that when the armature is rotated a weak current

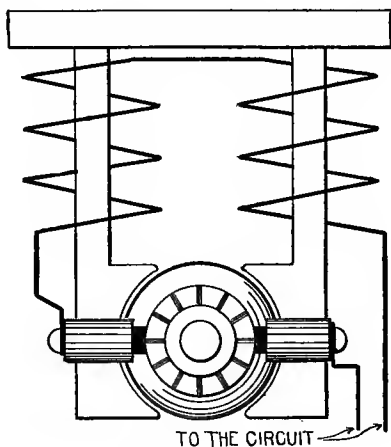


FIG. 44.—DYNAMO.

is produced. This current flows through the windings of the cores and increases their magnetism, which in turn increases the current produced in the armature. It takes only a very brief time to get the full intensity. A

generator of this kind, which obtains its magnetism from electricity, is called a **dynamo**.

On small stationary engines the ignition

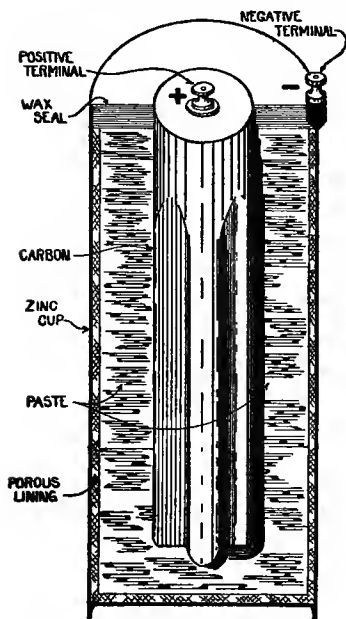


FIG. 45.—SECTION OF DRY CELL.

current is frequently obtained from a **battery** which is usually made up of **dry cells**. A dry cell consists of a zinc cup, a stick of carbon, and a paste which contains a chemical that under certain conditions will eat the zinc just as acid would eat it.

The space between the zinc cup and the stick of carbon is packed with the paste, but the carbon and the paste are prevented from

touching the zinc by a lining of blotting paper. (Fig. 45.)

A screw or nut attached to the carbon, and another attached to the zinc cup, form the terminals; when they are connected to the circuit an electric current will flow from the carbon to the circuit, returning to the cell by the zinc. The circuit must be complete, and the current will pass from the zinc to the moisture absorbed by the blotting paper, to the paste, and to the carbon.

No matter what the size of a dry cell may be its current will have a pressure of a little over one volt; a large cell, however, will give a greater quantity of current than a small one. As an ignition system will require a pressure of six volts to operate it, something must be done to bring the pressure up to this point.

Suppose a crowd of people to be so dense that a man cannot press his way through; if four or five men line up behind him, however, the pressure that they can exert by working

together will gain a passage. In a similar way dry cells can be made to work together, and to give any pressure that may be required. To do this the carbon terminal of one cell is connected to the zinc terminal of the next cell, as shown in Figure 46. The current of one cell must thus pass through the other cells in flowing over the circuit, and

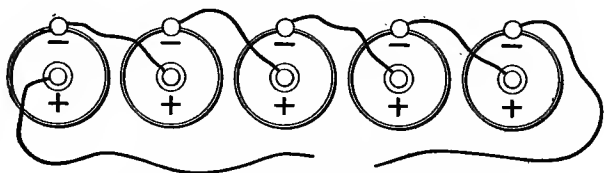


FIG. 46.—CELLS CONNECTED IN SERIES.

the voltage will be increased as many times as there are cells. If each cell gives one volt, for example, five cells connected in this manner will give five volts. This is called **connecting in series**.

While a cell may be capable of giving a considerable quantity of current this cannot be taken from it all at once. For instance, if a crowd of people try to rush through a nar-

row doorway they will become jammed in it; they can get through only by passing one at a time. A dry cell will act in a similar way, for while it will give a small current for a considerable time, it will become choked, so to speak, if a heavier current is taken from it. The flow of current will then cease entirely, and the cell must be permitted to stand idle in order to return to its former condition.

An ignition system will require the current at intervals, which gives the cells a chance to rest in between times. Under these conditions dry cells will give the best service that can be expected of them. If the circuit is closed, and is left so, the cells must supply current continuously, and will rapidly become exhausted. A wrench or other piece of metal laid on top of a dry cell will cause a **short circuit**; that is, it will provide an easy path by which the current may flow from carbon to zinc without going over the regular circuit. This will exhaust the cell, and should therefore be guarded against.

While it is customary for an engine manufacturer to supply an engine with five or six dry cells connected in series, the engine user will greatly improve matters by using ten dry cells, connected as shown in Figure 47. The cells are divided into two groups of five cells each, which are connected in series; the free carbon terminals of each group are con-

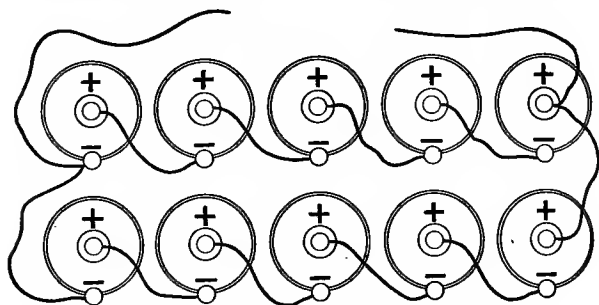


FIG. 47.—CELLS CONNECTED IN SERIES-PARALLEL.

nected together, and so are the free zinc terminals. Carbon and zinc are then connected to the circuit in the usual manner. This is called connecting in **series-parallel**.

Ten cells connected in series-parallel will give a current at the same pressure as five

cells connected in series, but will give a greater quantity of current; or what is more important, will give an equal quantity of current for a much longer time. Ten cells connected in series-parallel will last longer than ten cells used five at a time.

CHAPTER VIII

MAKE-AND-BREAK SYSTEMS

IN the **make-and-break** ignition system, which is also called the **low-tension** system, or, in other words, the low voltage or low pressure system, the circuit is closed to permit the current to flow, and is then abruptly broken. On the breaking of the circuit the current forms a spark in trying to continue to flow. The current may be obtained from a gear driven or an oscillating magneto, from a friction drive magneto or from a battery.

The current flows to the **igniter**, which is the device at which the circuit is made and broken, and at which the spark occurs. The igniter is attached to the cylinder in such a way that part of it projects through the cylinder wall and is in contact with the charge

of mixture; it is at this part of the igniter that the spark is produced.

During the inlet or compression stroke the engine causes two of the parts of the igniter to come together and to close the circuit; when the piston reaches the firing point the engine causes the two parts to separate and to break the circuit, and the spark forms between them.

One of these parts is a rod that extends through the cylinder wall, but which is carefully insulated from it. This rod is called the **insulated electrode**, or the **stationary electrode**, and sometimes the **anvil**. The other part is called the **movable electrode**, or the **hammer**, and is a small shaft that turns in bearings in the cylinder wall. It has a short arm on its inner end, so that when it turns in its bearings the arm may be touched to the stationary electrode or be separated from it.

Figure 48 shows an igniter cut through the center, and also two views of its inner end,

in one of which the circuit is closed, while in the other it is broken. The movable electrode may be turned in its bearings by means of the operating arm attached to its outer end.

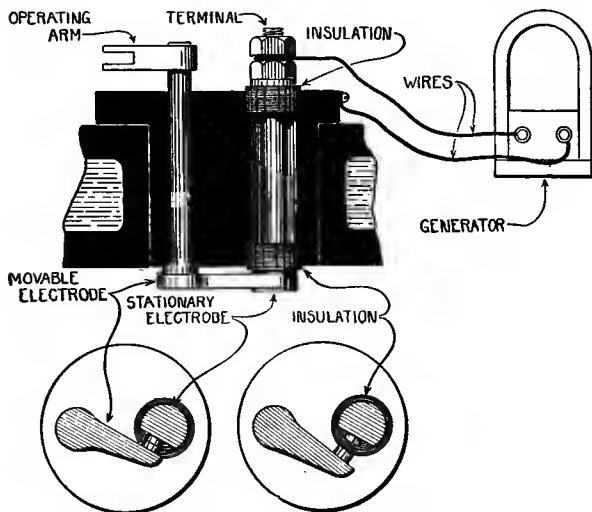


FIG. 48.—SECTION OF IGNITER.

As shown in Figure 48, one wire from the generator leads to the insulated electrode, while the other is connected to the metal of the engine. When the electrodes are sepa-

rated the current cannot flow, for, although the generator is connected to the insulated electrode, there is no way for the current to pass on to the metal of the engine. When the movable electrode is turned so that its arm touches the insulated electrode it gives the current its opportunity to pass from the insulated electrode to the metal of the engine, and so to return to the generator.

The two electrodes with their springs and other parts are usually mounted on an iron block, called the **igniter plate**, which is bolted to the cylinder, and the complete igniter may be removed when necessary.

Igniters are made in a great many different forms, but almost always work along the same general lines. A spring is arranged to pull the movable electrode against the insulated electrode, but a second and stronger spring acts against it and is able to hold the electrodes apart. Just before an ignition spark is required a rod or lever operated by the engine overcomes the heavy spring, which

permits the other spring to pull the movable electrode against the stationary electrode, and closes the circuit. At the instant when a spark is required the heavy spring is released, and in snapping back to its first position it strikes the movable electrode. The blow is sufficient to move the movable electrode away from the stationary electrode, which breaks the circuit.

The current that makes the spark is produced by magnetism, and in order that the current may be as intense as possible the magnetism should be made to die out very abruptly; this may be done by breaking the circuit suddenly. If the igniter points separate slowly a spark will be produced, but it will be a weak one; it will be much more intense when the points separate suddenly. The igniter is almost always made so that the movable electrode is moved by being struck instead of being pushed, for this breaks the circuit with great suddenness.

One method of doing this is shown in Fig-

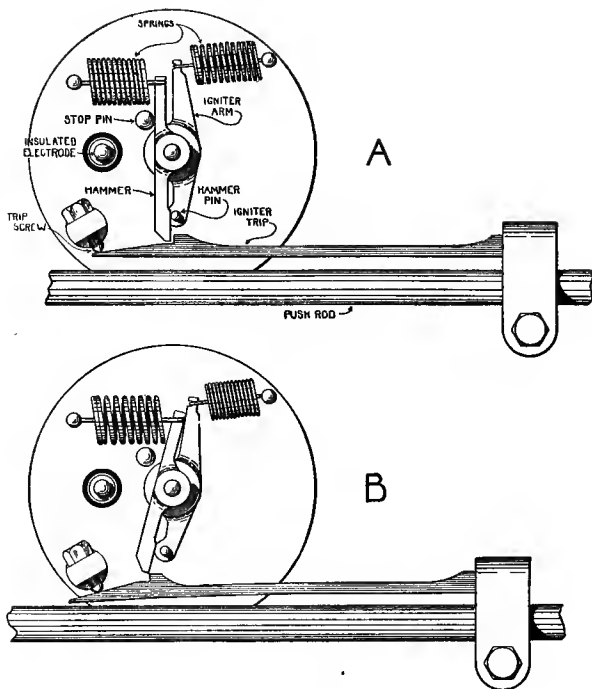


FIG. 49.—IGNITER MECHANISM.

ure 49. The igniter arm is attached to the end of the movable electrode, and it has an extension in the form of a small shaft, which acts as a pivot for the hammer. The strong spring is attached to the hammer, and holds it in position A when the igniter is not being operated. The hammer then presses against the hammer pin on the igniter arm, and thus holds the movable electrode away from the insulated electrode.

The igniter trip is a springy steel rod attached to a push rod, which is moved endways when the piston approaches the firing position. The shoulder on the igniter trip then catches the end of the hammer, moving it into position B. This releases the hammer pin, so that the weak spring is free to move the igniter arm, and to bring the movable electrode into contact with the insulated electrode. The sloping end of the igniter trip rubs against the stop screw, which causes it to bend down; when it bends sufficiently its shoulder releases the hammer, which snaps

back and strikes the hammer pin a sharp blow. This makes the movable electrode move very abruptly, and breaks the circuit.

By changing the adjustment of the stop screw the instant when the hammer is released may be changed, which will make a corresponding change in the instant at which ignition occurs.

Instead of the kind of springs shown in Figure 49 igniters are frequently fitted with springs that are wound around the pivot on which the hammer moves.

In the igniter shown in Figure 50 the hammer is not pivoted on the igniter arm, but is attached to a **tappet**, which is a rod sliding in guides, and fitted with a spring that tends to hold it in the position shown in the second sketch. When the push rod moves, the trip lever that is pivoted to it lifts the tappet, and thus permits the small spring to move the igniter arm and to close the circuit, as shown in the first sketch. One end of the trip lever rubs against a stop, and is moved by it; at

the instant when ignition is desired the trip lever moves from under the tappet, which is then driven downward by its spring. While thus moving the hammer strikes the igniter arm, moving it and breaking the circuit.

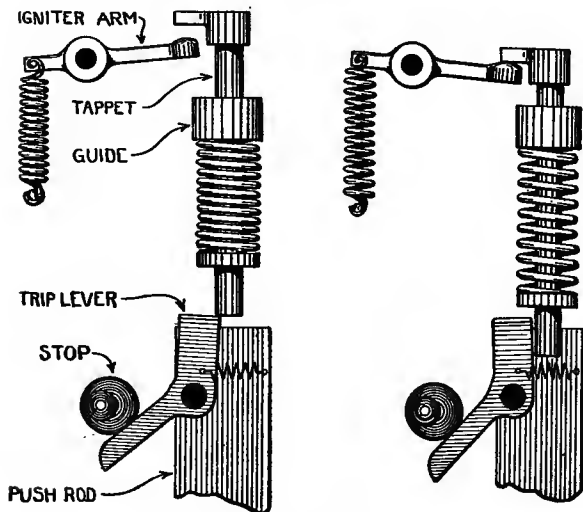


FIG. 50.—IGNITER MECHANISM.

Stationary engines are often so arranged that the spark may be changed while the engine is running, to permit the changing of the speed. When the engine is being started

the spark is retarded, being advanced when the engine is running to bring it up to speed. This is done by changing the stop so that the hammer may operate earlier or later in the stroke.

The constant hammering of the movable electrode against the insulated electrode, as well as of the hammer against the igniter arm, will eventually cause wear, which will interfere with the action of the igniter, and will put the ignition **out of time**; that is, the spark will no longer occur at the proper point in the stroke. The igniter must then be adjusted, which is done in accordance with the directions given in the instruction book furnished by the maker of the engine. It may be said in general that when the movable electrode is separated from the insulated electrode the spark points should be from $1/16$ inch to $1/8$ inch apart, and that the trip should release the hammer when its distance from the igniter arm is from $1/8$ to $3/16$ inch.

When the current for the make-and-break

ignition system is supplied by a positive drive magneto the connections consist of a single wire from the magneto to the insulated electrode. It was explained in Chapter VII that a positive drive magneto gives a sparking current only at certain points in the revolution of the armature, and that for this reason the magneto must be so driven that it is giving its sparking current when the piston is in the firing position.

In order to set or to time a magneto it is bolted to its base, but the driving gear is left loose on its shaft, so that the engine and the magneto may be turned independently of one another. The engine should be turned slowly to bring the piston to the firing position, and should be stopped just as the hammer is being released from the trip. If the igniter has two positions, one for starting and one for running, it should be placed in the running position. The cover over the magneto armature should then be removed, to permit the armature to be turned with the fingers until

it is in the position shown in Figure 51. In this position one of the metal heads of the armature will be uppermost, and the armature will be held by the magnetism. The driving gear should then be tightened on the shaft, great care being taken to prevent the moving either of the armature or of the engine while this is being done. The armature cover should then be replaced.

The magneto is thus set, or timed, to give its intense current when the piston is at the point in the stroke when a spark is required for full speed. When the magneto is

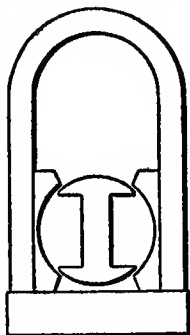


FIG. 51.—MAGNETO SETTING.

set it requires no further attention than two drops of good oil in each bearing once a week.

An oscillating magneto is so set that the armature and the igniter hammer operate together, and this is usually done by connecting the magneto trip lever to the movable electrode. This is illustrated in Figure 52.

When the magneto trip lever is released the heavy springs not only return the armature to its first position, but make it overrun a little, and it is then that the rod strikes the movable electrode and moves it.

The magneto trip lever must be set on the armature shaft so that when the trip is not acting the springs will hold the armature in the position shown in Figure 51 and in the upper sketch of Figure 52.

The use of a friction drive generator or of a battery requires a greater complication, for neither gives a sufficiently intense current by itself for ignition. The current given by a positive drive magneto may be used directly for the ignition, but the current given by a friction drive generator or a battery must be intensified by means of a coil.

The circuit consists of the generator or battery, with one terminal connected to the coil, while from the coil the current passes to the insulated electrode. The other terminal of the generator or battery is **grounded**; in other

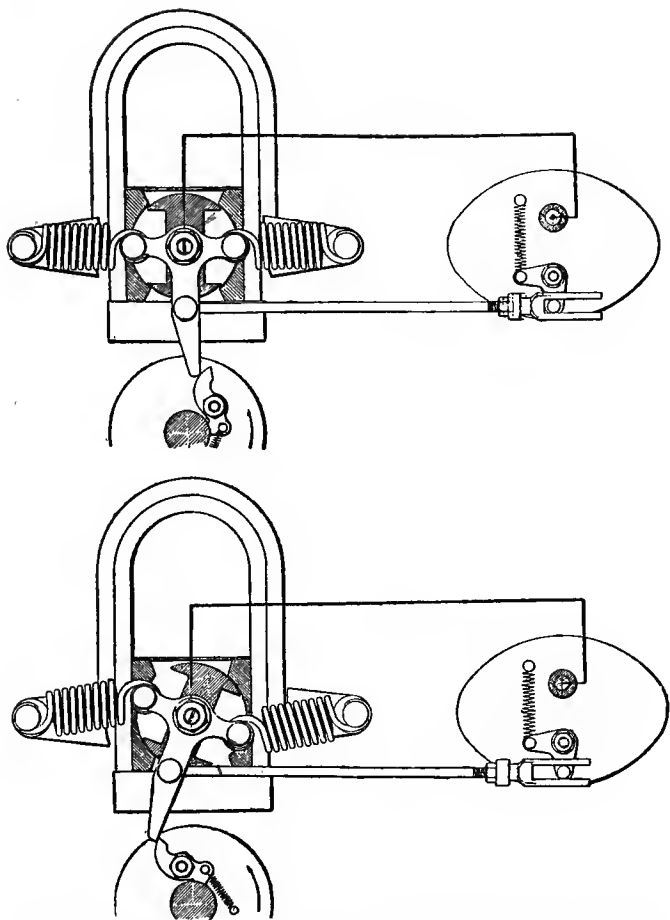


FIG. 52.—OSCILLATING MAGNETO FOR MAKE-AND-BREAK IGNITION.

words, it is attached to any metal part of the engine. Thus, when the igniter is making contact, the current flows through the coil to the igniter, to the metal of the engine, and back to the generator by the ground wire. This is shown in Figure 53.

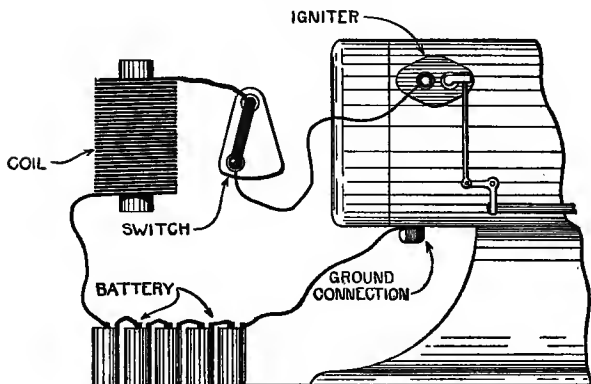


FIG. 53.—MAKE-AND-BREAK IGNITION BY BATTERY AND COIL.

The coil consists of a number of layers of coarse wire wound around an iron core; the core is a bundle of iron wires rather than a solid bar, because in that form it gains and loses its magnetism with greater rapidity. When the igniter points come together and

close the circuit the current flows through the coil winding and magnetizes the core; when the igniter breaks the circuit the current stops flowing and the magnetism dies away. While the magnetism is dying it produces an electric current in the winding of the coil, and it is this second current that forms the spark.

To demonstrate this action the experiment described in Chapter VI should be repeated. Take a 20-foot piece of insulated wire and attach one end to one of the terminals of a battery; when the other end is snapped back and forth across the remaining terminal of the battery a small spark will be seen. Now wind the wire around a small bar of iron, and it will be seen that the spark is much larger. Inasmuch as the battery and wire remain the same, the greater intensity of the spark can be explained only by the introduction of the magnetism that is produced by the flow of current around the iron bar.

In order to get a proper spark the core of

the coil must be given sufficient time to become thoroughly magnetized, and the igniter should therefore be so adjusted that the circuit will be closed for a long enough time. The manufacturer's directions for adjusting the igniter must be carefully followed.

A friction drive generator acts in the same manner as a battery, and is connected in the same way; that is, one terminal is connected to the coil and the other to the metal of the engine.

An ignition system should be fitted with a **switch** in order that the flow of current may be controlled. A switch is usually a strip of copper or brass, pivoted at one end so that it may swing from side to side. The plate supporting the strip of copper has a knob or contact in such a position that the strip, or **switch blade**, may touch it or be separated from it. The blade is connected to one wire and the contact to another; when the blade touches the contact the current may flow, but when the blade is moved away from the con-

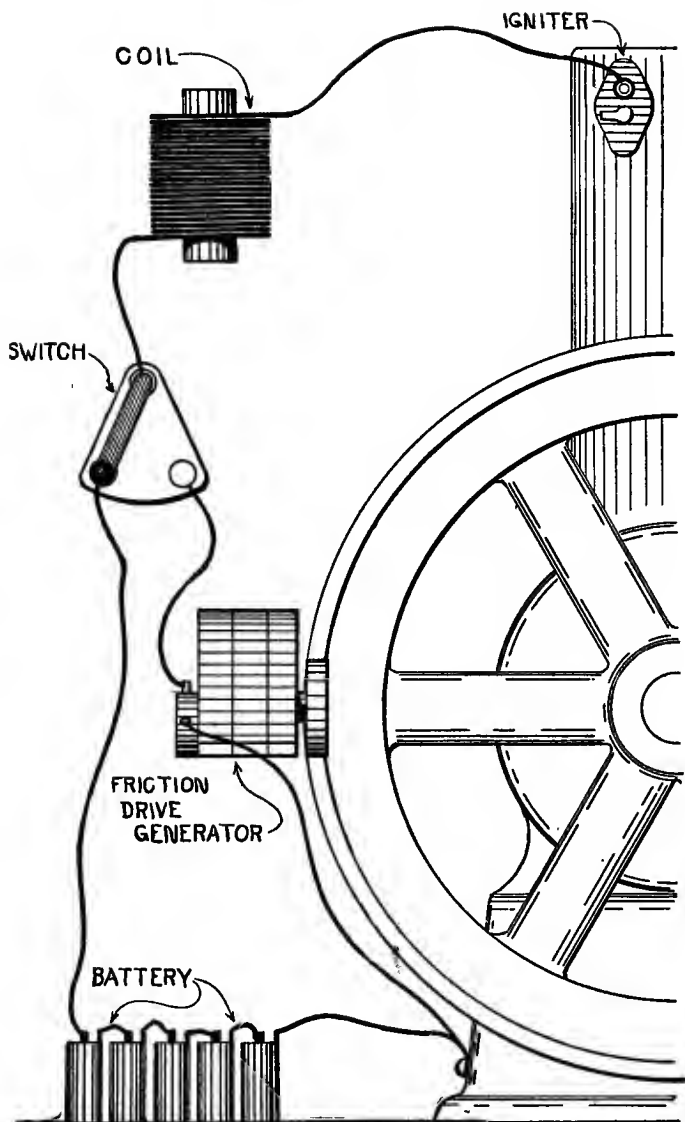


FIG. 54.—MAKE-AND-BREAK IGNITION WITH BATTERY AND FRICTION-DRIVE GENERATOR.

tact the circuit is broken. Figure 53 shows a switch with the circuit closed.

Engines are frequently fitted with both battery and friction drive generator, the intention being to start the engine on the battery, and to use the generator for running. The switch for this will have two contacts, one being connected to the battery and the other to the generator. (Fig. 54.) The switch blade is connected to the coil, so that by moving it to one contact or the other either the battery or the generator may be connected into the circuit. When the blade is between the contacts both circuits are broken, and ignition ceases.

CHAPTER IX

JUMP SPARK IGNITION SYSTEM

IN the jump spark ignition system, which is also called the **high tension**, or high pressure, system, two pieces of metal are set in the cylinder so that there is a space between them of a little less than $1/32$ inch; an electric current is caused to jump across this space, and it forms a spark in passing. The current that is used for the make-and-break system could not be used for this, because its pressure, or tension, is too low to enable it to jump across the gap. It is therefore necessary to use a current of very great pressure, or tension, just as it would be necessary to use a high pressure pump in order to raise water to a great elevation.

In the make-and-break system the spark is produced at the igniter, but in the jump

spark system it is produced at the **spark plug**, which has no moving parts, and is screwed into an opening in the cylinder.

There are three principal parts to a spark plug, one being a metal shell that is made with a screw thread, so that it may be screwed into the cylinder. (Fig. 55.) Inside of this is a stone, porcelain, or mica insulator, through the center of which passes a metal rod called the **center electrode**. These parts are so arranged that there is a space of $1/32$ inch or a little less between the center electrode and the end of the shell, or short wires set into it.

The shell of the spark plug is in contact with the metal of the engine, while the center electrode is insulated from it. The current is led to the center electrode, and jumps across the spark gap to the metal of the engine, for only in that way can it complete its circuit and return to the generator.

The parts of a spark plug should be so securely bound together that the pressure may

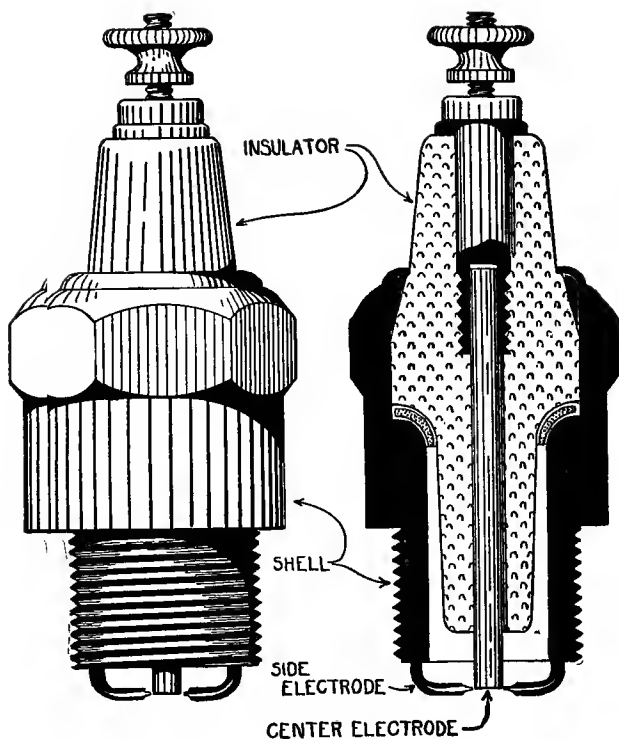


FIG. 55.—SPARK PLUG.

not leak from the combustion space, and they should not be injured by the intense heat. Lubricating oil will deposit on the spark plug, as it will deposit on all parts of the combustion space, and will be burned into carbon. Carbon is a conductor, and if it collects in the spark gap or on the insulator it will form a path that will permit the current to flow without jumping. This can be prevented by making the plug with a large surface on the insulator, as shown in Figure 55.

The spark plug has a most difficult service to perform, and the satisfactory and continued operation of the engine is so dependent on it that in the long run the high grade and necessarily expensive spark plug is far cheaper than the one that is low in grade and price.

The simplest and most reliable method of producing a sparking current for the jump spark system is by means of a positive-drive **high-tension** magneto, which produces its own sparking current without the need of a

coil. A high-tension magneto is the same in principle as the make-and-break magneto, except that instead of a single winding of coarse wire it has two windings. One of these, called the **primary winding**, consists of a few layers of coarse wire, on top of which is the other winding, called the **secondary winding**, made up of a great number of layers of very fine wire. The primary winding is connected to a device called the **circuit breaker**.

Every ignition system must have some way of controlling the instant at which the spark is produced; on the make-and-break system the igniter is tripped when the spark is required, and is thus the controller of the instant of sparking, or the **timer**, as well as the spark apparatus. As a jump spark plug has no moving parts it cannot be used in this way, and a high tension magneto therefore has the timing device built into it, which greatly simplifies the system.

The timer, or circuit breaker, consists of

two platinum points, one on the tip of an insulated screw and the other on a lever that is so arranged that the platinum points may come together to close the circuit, or be separated to break the circuit. These parts may be seen in Figure 56, which is a diagram of a high-tension magneto.

In the diagram the two windings are shown side by side, but this is only for the sake of clearness; in a magneto the secondary winding is wound on top of the primary winding. The diagram also shows one end of the primary winding connected to the circuit-breaker lever, and also to the shell of the spark plug. This, too, is for the sake of clearness; in a magneto this end of the primary winding is screwed to the metal of the armature core, and is therefore grounded. As the circuit breaker lever is pivoted to the metal of the magneto a current will have a metal path from the grounded end of the primary winding to the circuit breaker lever. When the spark plug is screwed into

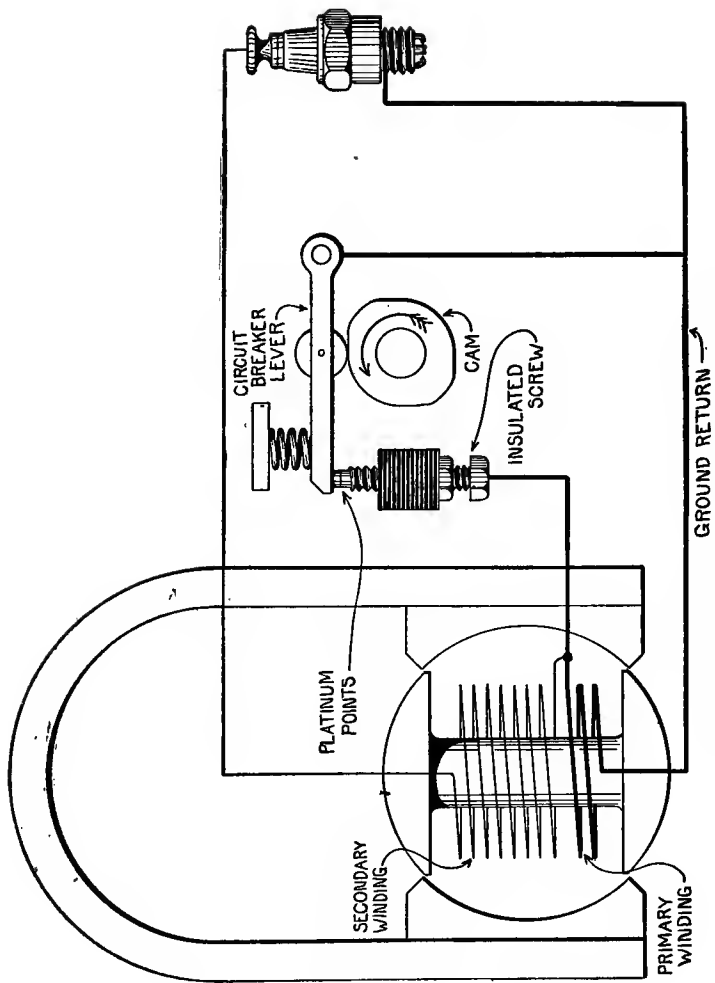


FIG. 56.—DIAGRAM OF HIGH-TENSION MAGNETO.

the cylinder its shell touches the metal of the engine, and as the magneto is bolted to the engine an electric current may flow between the magneto and the spark plug shell.

The free end of the primary winding is connected to the platinum tipped screw. When the circuit breaker lever touches the screw, as shown in Figure 56, the primary circuit is closed; that is, a current may flow from the primary winding to the screw, to the lever, and back by the metal of the engine to the grounded end of the primary winding. When the lever moves away from the screw the circuit is broken.

The lever is made to move, and to close or break the circuit, by a cam that revolves against it. The cam is attached to the armature shaft and revolves with it.

It will be seen in Figure 56 that one end of the secondary winding is connected to the free end of the primary winding, and that the other end leads to the center electrode of

the spark plug. One winding is thus a continuation of the other.

When the armature revolves the magnetism acts on it as described in Chapter VII. During the time when the current is weak the circuit breaker is closed to permit the current to flow in the primary winding. The magnetism also tries to produce current in the secondary winding, but with no result, because the pressure is not sufficient to jump across the gap in the spark plug. When the armature reaches the point at which the current in the primary winding is most intense the lever moves and breaks the circuit. The current desires to continue flowing, and as it can no longer pass across the platinum points the only path left for it is through the secondary winding. The sudden rush of the intense primary current into the secondary winding raises sufficient pressure to enable the current to jump across the spark plug gap, where it forms the ignition spark.

This is the action of a Bosch high-tension

magneto, which is in very general use because of its reliability. In Figure 56, however, the circuit breaker lever and insulated screw are stationary, while the cam revolves; in the Bosch magneto, on the contrary, the circuit breaker lever and insulated screw re-

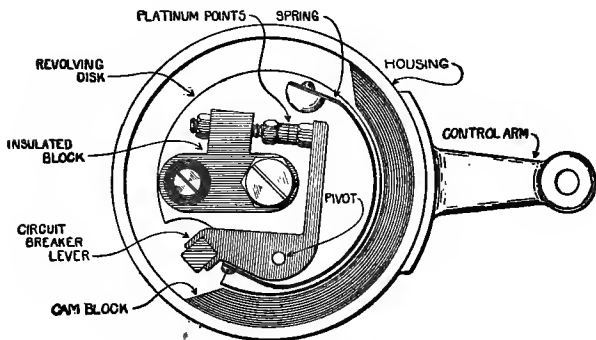


FIG. 57.—BOSCH CIRCUIT BREAKER.

volve with the armature, while a stationary steel block takes the place of the cam. The Bosch circuit breaker is shown in Figure 57.

The circuit breaker lever is L-shaped, pivoted at the angle, and at one end it has a platinum point. A flat spring presses this end of the lever against a platinum tipped

screw set in the insulated block, and all of these parts are supported on a disk that is secured to the armature shaft by the central bolt. As may be seen from Figure 58, this bolt conducts the primary current to the insulated block.

When the armature revolves the outer end of the lever strikes the end of the cam block that is attached to the inside of the housing; this causes the lever to move on its pivot and breaks the circuit at the platinum points. It is at this instant that the spark is produced.

The housing has a control arm attached to it by which it may be turned partly around; this permits the spark to be advanced or retarded. When the housing is turned as far as it will go in the opposite direction to the way that the armature is turning, the lever will strike the cam block when the armature is in position C, Figure 38. The spark will then be advanced, and it should be in this position when the engine is running.

When the housing is turned as far as it

will go in the same direction as the armature is turning, the lever will not strike the cam block until the armature has moved to position D, Figure 38. The spark is then retarded, and it should be in this position when the engine is being started.

In the ordinary magneto it is necessary to run the armature at a much higher speed to get a spark in the retarded position than in the advanced. In the Bosch high-tension magneto, however, the **pole shoes**, which are curved iron blocks attached to the magnets, are so made that a spark will be obtained at as low or even lower speed in the retard as in the advance. This is a great advantage, as it makes an engine easy to start.

Figure 58 shows the outer end of the secondary winding attached to a **collecting ring**, or **slip ring**, which is a grooved hard rubber wheel, with a brass ring set in the bottom of the groove. The collecting ring is secured to the armature and revolves with it. A carbon brush is pressed against the metal ring

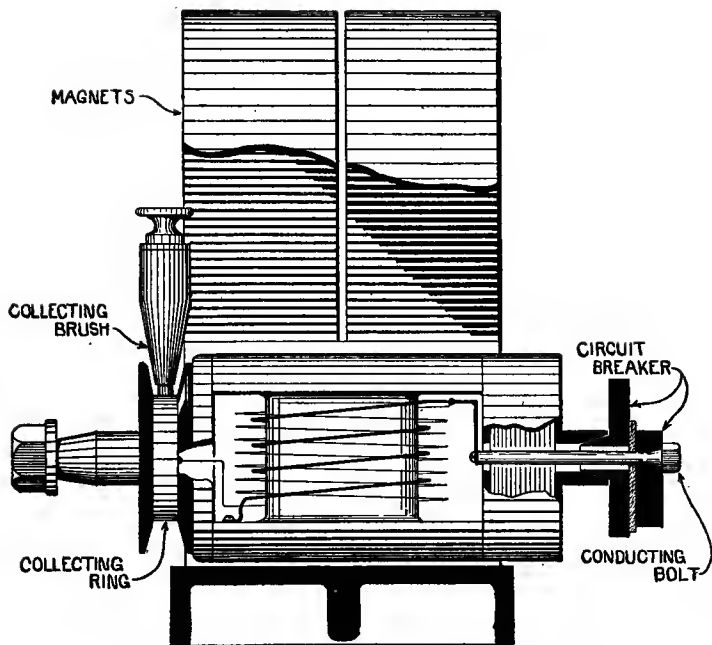


FIG. 58.—DIAGRAM OF BOSCH HIGH-TENSION MAGNETO.

so that the ring in revolving rubs against it; the secondary current flows to the ring, to the brush, and thus to the spark plug.

The only attention required by a Bosch high-tension magneto is to put two drops of good oil in each bearing once every two weeks; the circuit breaker lever takes care of itself, and should not be oiled. Beyond this occasional oiling a Bosch magneto gives best results when left entirely alone.

This magneto is also built in oscillating form, a trip lever with springs being attached to the armature shaft. The circuit breaker is different in arrangement, as may be seen by Figure 59, the lever being operated by a flat place on the stationary steel bushing that forms one of the armature bearings.

The Witherbee igniter is illustrated in Figure 60. It consists of two iron cores, each carrying a coil of wire, and across which are placed magnets in the form of flat bars. A plate of iron, or armature, is placed at each

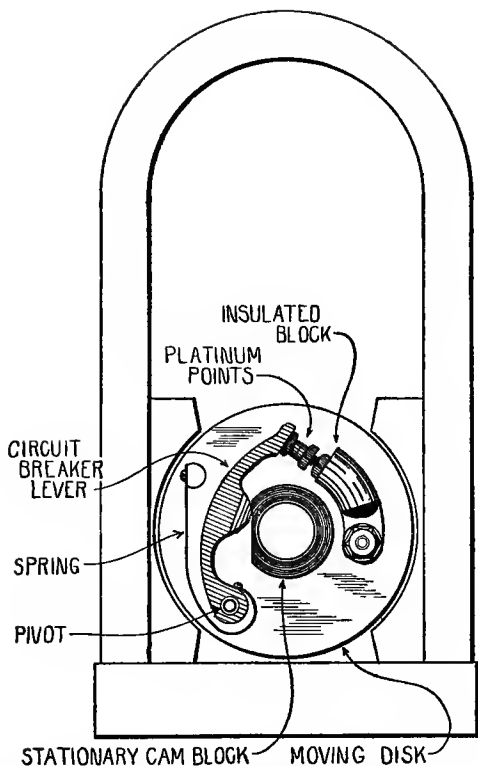


FIG. 59.—CIRCUIT BREAKER OF BOSCH OSCILLATING HIGH-TENSION MAGNETO.

end, the two armatures being supported by a driving bar passing through them. Either one of the armatures may be brought into contact with the cores, to form a bridge by which the magnetism may flow; the flow of magnetism is indicated by the arrows. When the driving bar is raised, as shown in the first sketch, the lower armature forms the bridge, and the cores become magnetized. When the driving bar is released by the cam, as shown in the second sketch, the spring drives it downward, and with great abruptness it knocks the lower armature away from the cores, at the same time bringing the upper armature into contact with them. The dying out of the magnetism in the cores produces a jump spark current in the coils.

The diagrams show the driving bar operated by a cam; in the machine itself the cam or eccentric operates a tripping device that in turn lifts the driving bar.

When batteries and friction drive generators are used for jump spark ignition, the

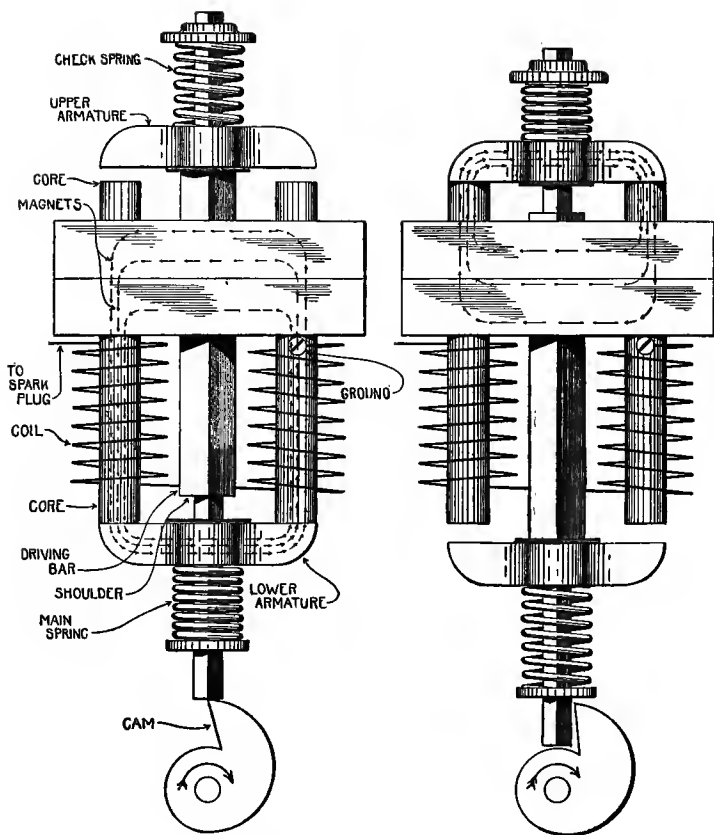


FIG. 60.—WITHERBEE IGNITER.

current that they give passes to a **high-tension coil**, or **vibrator coil**, as it is also called, which gives it sufficient pressure to jump across the spark plug gap. A high-tension coil consists of a core on which are wound a primary and a secondary winding; in this it is similar to the armature of a high-tension magneto, except that the windings are separate instead of one being a continuation of the other.

The principle of a high-tension coil is shown in Figure 61. This shows an iron core with a winding of wire on each end, the ends of one winding being connected to a battery through a switch, while the ends of the other are brought close together. When the battery current flows through its winding the core becomes magnetized, and the magnetism dies away when the battery current stops flowing. These changes in the magnetism are felt by the other winding, and each time that a change occurs electricity is produced in it. If the magnetism dies away very suddenly,

the current that will be produced in the second winding will be able to jump between the ends, and will form a spark. To produce a spark the core must be magnetized, which is done by closing the switch to let the battery current flow, and then the magnetism

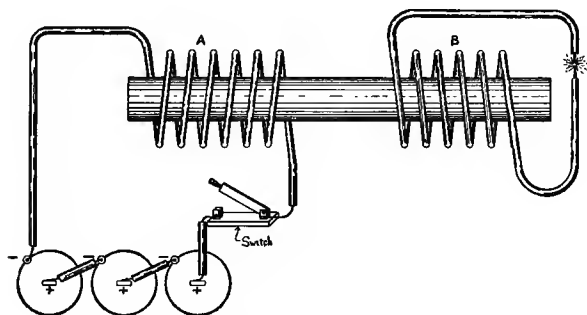


FIG. 61.—PRINCIPLE OF HIGH-TENSION COIL.

must be made to die away, which is done by opening the switch to stop the flow of current. The spark is produced while the magnetism is dying away.

The principle is the same whether the windings are side-by-side, as in Figure 61, or one on top of the other, and in the coils

used for ignition the battery coil, or **primary winding**, is wound on the core, with the sparking coil, or **secondary winding**, wound on top of it. This gives better results and makes the coil more compact. As is the case with the high-tension magneto, the primary winding consists of a few layers of coarse wire, while the secondary winding consists of a great number of layers of very fine wire.

In order to produce an intense current in the secondary winding the magnetism must be made to die away very suddenly, which results from stopping the flow of current very abruptly. This is done by a **vibrator**, which makes and then breaks the circuit with great rapidity, and thus causes a succession of sparks to be produced by the secondary winding. The vibrator is operated by the magnetism of the core, which acts on a **vibrator blade** that is placed opposite one of its ends.

The parts of a vibrator are shown in Figure 62; its parts are connected to the primary winding, and the sketch shows the core

with the primary winding wound on it. The vibrator blade is a flat steel spring, solidly supported at one end, and with the other end opposite one end of the core. The blade rests against a platinum tipped screw, and the circuit is made and broken between this plati-

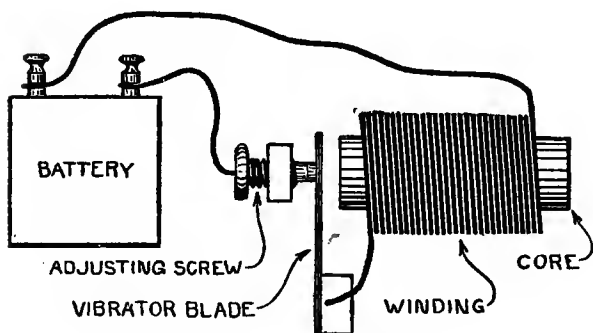


FIG. 62.—ACTION OF VIBRATOR.

num tip and a piece of platinum attached to the blade.

As the diagram shows, one terminal of the battery is connected to one terminal of the coil, while the other battery terminal leads to the platinum tipped screw; the vibrator blade is connected to the remaining coil ter-

minal. The circuit is thus closed, for the current can flow from the battery to the screw, to the blade, and through the coil back to the battery. The flow of current through the coil magnetizes the core, however, and the magnetism draws the blade to the core. This separates the platinum points, which breaks the circuit; the current then stops flowing, the magnetism dies away, and the blade springs back and closes the circuit again. The vibrator blade is thus in constant motion, and every time that it breaks the circuit it causes a sudden dying away of the magnetism that in turn produces a sparking current in the secondary winding.

The coil may thus be considered as an apparatus that will transform the low pressure current given by a battery or by a friction drive generator to a current of sufficiently high pressure to jump the gap in the spark plug.

In order to complete this ignition system it is necessary to have some means of control-

ling the instant when the spark passes in the plug. Without a device to do this the coil would be acting and producing sparks during all of the time that the engine was running, which would waste the electric current and would interfere with the operation of the engine by setting fire to the mixture before the proper time. This device is called the **timer**, and it is nothing more nor less than a switch that closes the battery circuit when a spark is required, and breaks the circuit when the spark is no longer needed. The timer is the same in principle as the switches shown in Figures 53 and 54, but instead of swinging from side to side its moving part revolves.

For a one-cylinder engine a timer consists of a ring of hard rubber, fiber, or some other insulating material, with a metal plate or contact set in its inner surface. (Fig. 63.) Inside of the ring is a metal or carbon brush set on the end of the timer shaft in such a manner that when the shaft revolves the brush drags around the inner surface of the

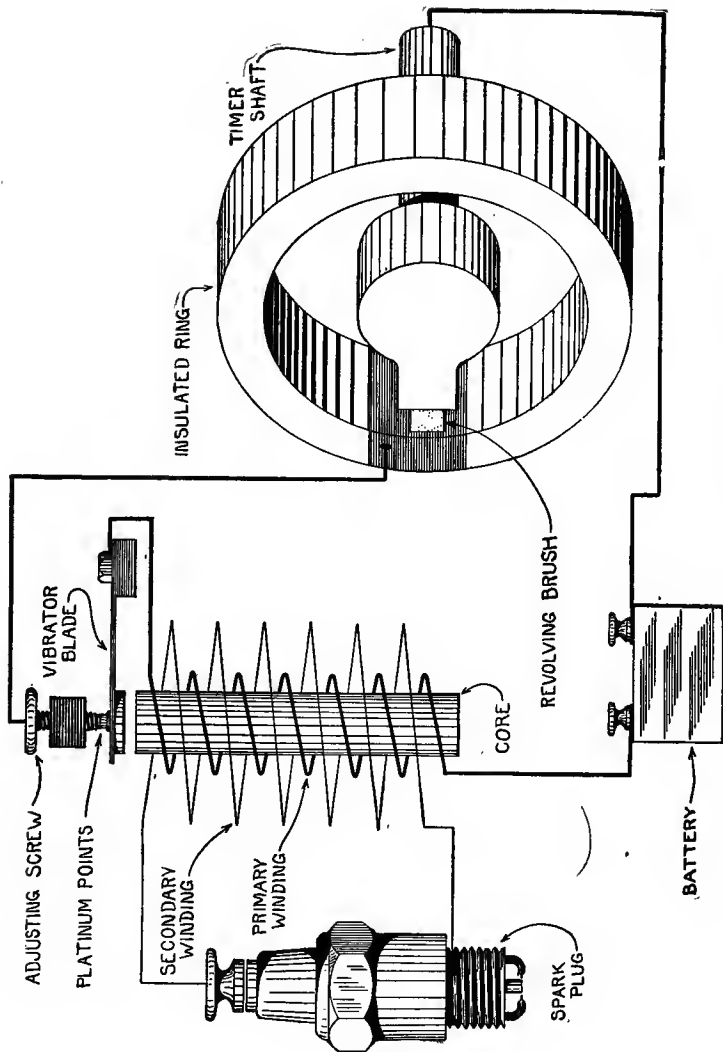


FIG. 63.—JUMP SPARK IGNITION WITH VIBRATOR COIL.

ring. The shaft is in contact with the metal of the engine, so that current may flow to the brush; the contact plate, on the other hand, is connected to one of the coil terminals.

When the brush touches the contact plate it closes the circuit, for then the current can flow from the battery through the coil and vibrator to the timer contact, and by the revolving brush and the metal of the engine back to the battery. This causes the vibrator to operate, and the high-tension current then produced in the secondary winding passes to the spark plug.

Timers are made in a great variety of designs, and always with the idea of making a good contact, and of preventing interference by the entrance of dirt. The timer ring is usually provided with an arm that will permit it to be turned part way around, so that the circuit will be closed early or late in the revolution of the shaft; by this means the spark may be advanced or retarded.

Like all other electrical devices, the timer

has a place at which the current may enter, and another at which it may leave. One of these is a nut or screw on the contact plate, to which the coil is connected; the other is the timer shaft by which the current may flow to the metal of the engine and thus to the battery ground wire.

CHAPTER X

LUBRICATION AND COOLING

A DEFECT in ignition or carburetion will slow down an engine or stop it, but a defect in the oiling of the engine may cause an injury or breakage of the parts. The necessity for exercising extreme care in the oiling of the engine thus becomes apparent.

When two pieces of metal are rubbed together the friction will heat them, and the heat will cause them to expand. If one of the pieces is the piston and the other is the cylinder, the result will be the sticking or seizing of the piston in the cylinder and the scratching of the piston rings and cylinder walls. When two pieces of metal must move one against the other, as a shaft turns in its bearings or as a piston slides in the cylinder, they

are prevented from rubbing by the introduction of oil between them. The oil thus forms a bed or cushion on which the moving piece turns or slides.

The moving piece tends to use up the oil partly by crushing it, and partly by pushing it out, and it thus becomes necessary to keep up a continuous supply of oil in order to compensate for what is used. A bearing is supplied with oil rather than with water or some other liquid because oil clings to the surfaces and resists being squeezed out. The thicker an oil is the greater is its ability to cling to the surfaces and to stay in place; a thick oil or a grease is used when the moving part is very heavy, for in such a case the great weight would squeeze out a thin oil and the two metal surfaces would rub.

The most usual lubricating oil is known as machine oil, and it is of a thickness that makes it useful for lubricating all ordinary machinery. Machine oil can be used for oiling the crank shaft and cam shaft bearings

of a gas engine, but should never be used to oil the piston and cylinder walls. The reason for this lies in the extreme heat existing in the cylinder. When oil is heated it becomes thin and finally burns, and any ordinary oil will be burned by the heat of the cylinder before it has time to do any lubricating. It will therefore be unable to prevent the piston from rubbing against the cylinder walls. Even the very best oil will not last long in the cylinder, but while it lasts it will prevent the surfaces from rubbing.

Lubricating oil has no harder service to perform than the oiling of a gas-engine cylinder, and a kind of oil that is made to stand the heat is absolutely necessary. This is known as **gas-engine cylinder oil**, and it should invariably be used. It is very poor economy to use cheap oil, for the expensive and high grade oil will cost less in the long run.

There are a number of systems for supplying oil to the engine, one being the splash

system, which is particularly adapted to vertical engines. To make use of the splash system the engine crank case must be enclosed, and oil is permitted to stand in it to such a depth that the end of the connecting rod just dips in when the piston is at the outer end of the stroke. When the engine is running the connecting rod splashes the oil to all parts of the crank case, and to the bearings of the crank shaft and cam shaft. The oil that falls on the piston is spread on the cylinder walls as the piston moves inward, and works its way up to the combustion space, where it is finally burned.

The loss of oil is made up by adding oil to the crank case so that the proper depth is maintained, and for this purpose an **oil cup** is usually used. An oil cup is a small, glass-sided tank so made that the flow of oil from it may be regulated by means of a needle valve. The mechanism of an oil cup is shown in Figure 64. The oil flows out through the needle valve, which may be adjusted by a nut set

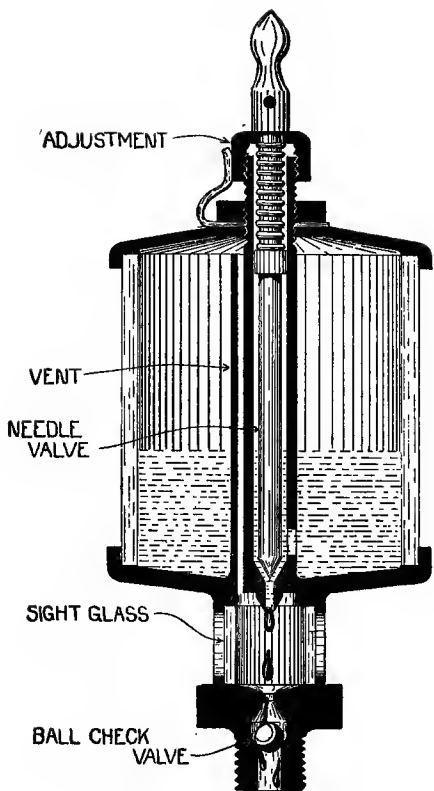


FIG. 64.—OIL CUP.

on the upper end of the sleeve through which the needle valve passes; the number of drops passing may be seen at the sight glass. A ball check valve prevents the pressure in the cylinder from escaping; if pressure leaks past the check valve it will escape through the vent without interfering with the flow of oil.

An oil cup of this sort will feed oil whether or not the engine is running. When the engine is stopped the flow of oil must be shut off, and this is done by turning down the upper handle, on which the spring forces the needle valve down and closes the passage.

When the splash system is not used it is usual to provide an oil cup for each bearing, or in some cases to attach an **oiler**. An oiler consists of a number of small pumps placed in an oil tank and driven by the engine. Each pump is connected to a bearing or to an opening in the cylinder wall, and forces a certain quantity of oil to that bearing at regular intervals for as long as the engine runs.

The best oil and the best oiling system

would be useless if the engine were not provided with some method of reducing the intense heat; every engine has a cooling system

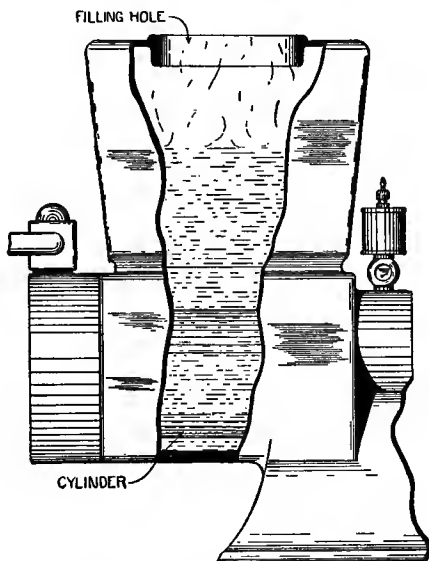


FIG. 65.—HOPPER-COOLED ENGINE.

that cools the cylinder to a point at which the oil will not be instantly burned. This is usually done by providing for a flow of water around the cylinder in channels called **water jackets**; these may be seen in Figures 4, 5, 6,

13, and others. The only difference in water-cooled engines is in the method of circulating the water.

In the **hopper-cooled** engine a tank is attached to the cylinder, as shown in Figure 65.

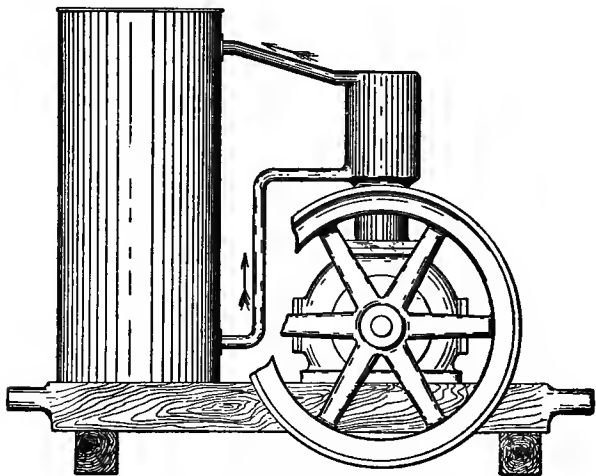


FIG. 66.—TANK-COOLED ENGINE.

The hopper and water jacket are filled with water, which is gradually evaporated by the heat. The water level should always be high enough to keep the cylinder covered.

In the **tank-cooled** engine a tank is placed

beside the engine and the water jacket connected to it by a pipe slanting up from the top and another slanting down from the bottom. (Fig. 66.) As the water in the jacket becomes heated it tends to rise, and passes

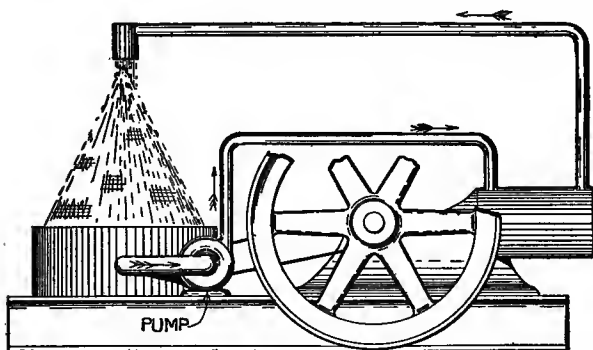


FIG. 67.—PUMP-COOLED ENGINE.

out by the upper pipe. Its place in the jacket is taken by cool water entering at the bottom, and this circulation continues as long as the engine runs. The water should stand in the tank above the upper pipe.

In the **pump-cooled** system the water is circulated by means of a pump driven by the

engine that forces the water through the jacket and to some form of cooling apparatus. (Fig. 67.) The cooler illustrated is a tank over which is a cone of wire netting. The water flows from the pipe to the point of the cone, and is cooled by the surrounding air in running down the surface.

In these circulating systems the water that is heated in the jackets is cooled by contact with the surrounding air. In many cases the cylinders are cooled by direct contact with air and without the use of water. In order to make this practical the cylinder should have a very large surface, so that as much air as possible will be in contact with it. This is accomplished by casting deep flanges on the cylinder, as shown in Figure 68. In order to make air-cooling effective the air must be kept moving around the cylinder, and this is accomplished by a fan driven by the engine that blows a current of air against the cylinder flanges.

In Figure 69 is shown a cylinder that is

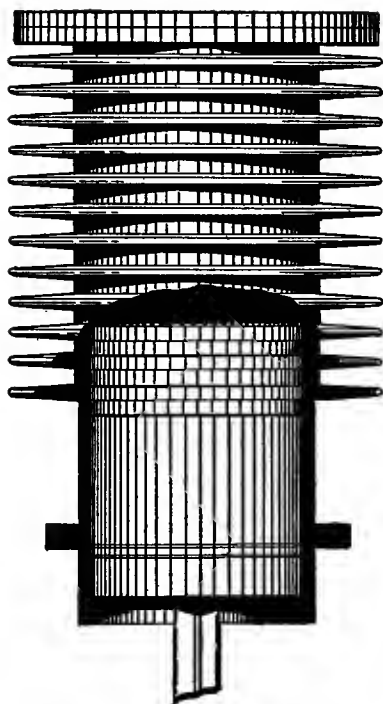


FIG. 68.—AIR-COOLED CYLINDER.

surrounded by a sheet-metal jacket that confines the air from the fan, and forces it to circulate around the flanges. The jacket is open

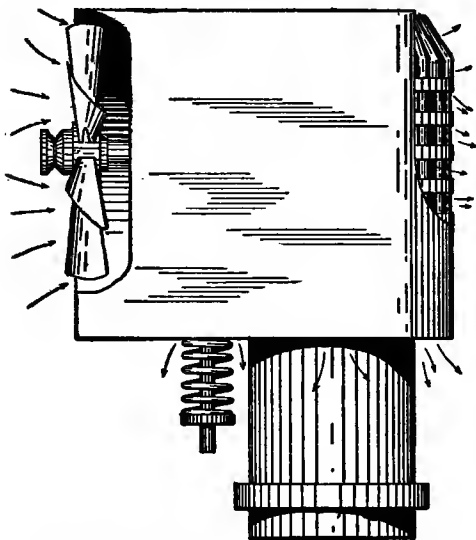


FIG. 69.—FORCED-DRAFT COOLING SYSTEM.

at the side opposite to the fan, and also at the bottom; as the flanges are made with holes the air may pass down as well as across, and thus reach all parts.

A properly constructed air-cooled engine is

unaffected by low temperatures that might freeze the water of a water-cooled engine that is standing idle. In order to make air-cooling successful, however, the cylinder flanges must be kept clean, for a coating of dust and grime on them will interfere with the passing off of the heat.

CHAPTER XI

POWER

AN automobile is usually purchased with the idea of using it for pleasure and convenience, and its selection is quite likely to depend on the arrangement of the body, the color, or any one of a score of details that are matters of personal preference. The purchase of a stationary engine is a very different proposition, for it is to be used in a man's business and will be expected to earn money for him. The selection of the engine should therefore depend on reliability, and in a lesser degree on efficiency; the efficiency of the engine being considered as the cost of the gasoline, oil and other supplies that it requires in the doing of its work.

The breakdown of an automobile is an in-

convenience, but the breakdown of a stationary engine causes a direct money loss; a loss of the value of the work that the engine might be doing, and the loss of interest on the money invested in it. For every hour that an engine works it is paying a return on the money spent in its purchase; for every hour that an engine stands idle, either through breakdown or because there is nothing for it to do, there is a dead loss. The man who conducts his affairs on a systematic and business-like basis will buy the most reliable engine obtainable, will provide a full day's work for it every day, and will give it the care necessary to keep it in first-class condition.

A well-built, well-equipped engine will run for year after year without breakdown and without repair expense if it is given common-sense attention; and it may be added that this attention costs only the value of a few daily minutes.

The small stationary engine seems to be expected to break down every little while, and

experience frequently justifies this opinion. A little investigation, however, will show that in a great majority of cases the breakdown is due, not to the engine itself, but to the carburetion system, or to the ignition system, or to neglect and carelessness.

Buyers of small stationary engines usually consider only the cost of purchase, and lose sight of the cost of maintenance and operation, as well as the greater losses that may result from a breakdown. They demand an outfit at a low price, and the manufacturer has no choice but to supply it. The money that they are willing to pay will not permit the engine to be fitted with high-grade accessories, and breakdowns and poor service are to be expected in consequence.

This condition will continue until the buyer learns that for every dollar saved on the purchase price he may lose two through breakdowns. Cheap coils, cheap wire and switches, cheap batteries, will give correspondingly poor service, but the buyer will

continue to get this poor equipment just as long as he insists on giving a poor price. The instruction books issued by a number of engine manufacturers contain the statement that 75 per cent. of engine troubles are due to ignition, which suggests the improved service that would be given by these same engines, when high-grade and reliable ignition systems are substituted for the cheap and faulty outfits that the low price forces the makers to use.

The selection of an engine is, of course, determined by the work that is to be done, and makers of feed choppers, separators and other machines will always inform a purchaser of the power that will be required to drive them. This will be stated as being so-and-so many horse power. The term horse power is somewhat misleading; the work that can be done by a 4-horse power engine, for instance, can hardly be compared to the work that four horses can do, because it is applied in a different manner.

A certain piece of work may be said to require a certain horse power, just as a field is said to contain so many acres, or a tank so many gallons. The size of the acre and the volume of the gallon have been established through long usage, and this is also the case with the value of the horse power by which work is measured.

Another thing that is at first confusing is to see on the one hand a stationary engine weighing perhaps 1,000 pounds and delivering 5-horse power, and on the other hand an automobile engine of less than half the weight but delivering 20-horse power. To make the difference clear it is only necessary to compare the conditions under which the two engines run.

An engine gets its power from the pressure produced by the burning of the charge of mixture, and the larger the charge the greater will be the pressure. The cylinder of the 5-horse power stationary engine is twice the size of a cylinder of the 20-horse power au-

tomobile engine, and its power stroke will turn the crank shaft with twice the force. The automobile engine, however, runs at twice the speed of the stationary engine, so that while the stationary engine is making one power stroke, any one of the cylinders of the automobile engine will be making two power strokes. The force applied to the crank shaft is therefore the same in both cases.

Each cylinder of the high-speed automobile engine develops as much power as the large cylinder of the slower speed stationary engine; it follows that its four cylinders acting together will develop four times the power.

The power that an engine can develop depends in the first place on the size of its mixture charges, which is in accordance with the size of the cylinder and the length of the stroke, and in the second place on the rapidity with which its power strokes follow one another, which is in accordance with the speed. Of these two, the engine speed is the

important thing to consider, for it must be in accordance with the speed of the machinery that is to be driven.

It is very natural to inquire why a heavy, slow-speed engine should be used when equal power can be obtained from a light weight automobile engine, and the answer brings out a number of reasons. In the first place, even the slow speed of a stationary engine is usually greater than the speeds at which machinery should be driven, and the speed is reduced to the proper point by using a large pulley on the machine and a small one on the engine. If a high-speed engine is used the necessary reduction will be so great that it will cease to be practical because of the slipping of the belts.

For another thing, while the automobile engine may be capable of driving a car at sixty miles an hour, it is not required to do so very often, and then only for brief periods. It is usually developing only a small proportion of the power of which it is capable, and the

parts of the engine may be made comparatively small and light. A stationary engine, on the contrary, is almost always working up to its limit, and its parts must be large and heavy in order to prevent their rapid wear.

As the cylinders of the automobile engine are small, the charges of mixture do not produce very great pressure, and the cylinder walls and head, the piston, and other parts, may be light. The much larger charges of a stationary engine require the cylinder, piston, connecting rod, crank shaft and other parts to be heavier and more substantial; this is another reason for the greater weight.

A stationary engine is built to run at a certain definite speed, and at that speed the valve openings and the compression will allow it to produce its greatest power. This is known as the **normal speed**. At lower speeds the power will naturally fall off, and at higher speeds not enough time will be allowed for all of the burned gas and for full charges of fresh mixture to pass through the valve openings.

An engine should not be given so heavy a load as to prevent it from running up to its normal speed, and it is prevented from running faster than its normal speed by a **governor**.

A machine that requires 5-horse power to drive it will hold a 5-horse power engine at normal speed, but a 10-horse power engine would have more than enough power, and if it were not checked it would speed up excessively; or as the engineer says, it would **run away**. The object of the governor is to prevent the engine from running beyond its normal speed, no matter how light may be the load that it is driving.

The action of a governor is controlled by the speed of the engine, and is dependent on **centrifugal force**, which is the force that tends to throw things away from the center around which they are revolved. It is centrifugal force, for instance, that makes water fly from a revolving grindstone.

The governor of a small engine usually consists of one or two iron weights on the ends

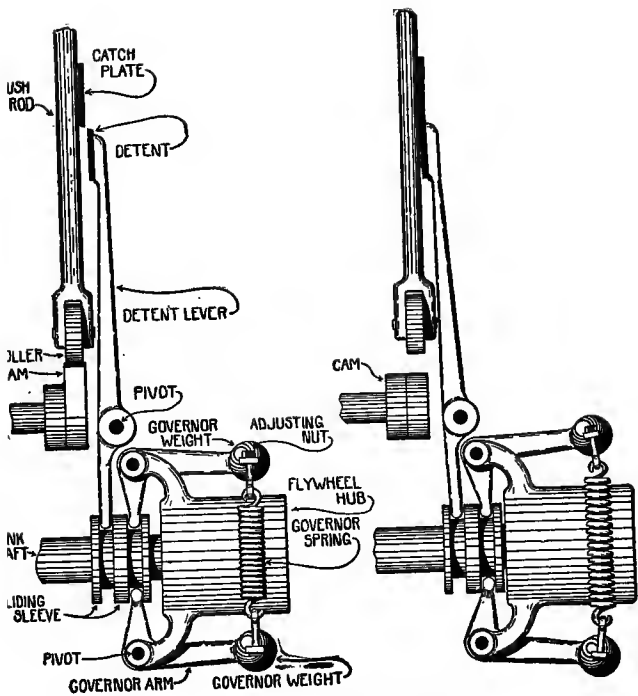


FIG. 70.—FLYWHEEL GOVERNOR.

of arms that are pivoted to the crank shaft or some other revolving part of the engine. Figure 70 shows two curved arms projecting from the hub of the flywheel; the governor arms are L-shaped, and pivoted to the curved arms. The weights on the ends of the governor arms are connected by two springs, one on each side of the hub, and while the governor arms may move on their pivots they must stretch these springs in order to do so.

The other ends of the governor arms catch in a groove on a metal ring or sleeve that is so arranged that it revolves with the crank shaft, but at the same time is free to slide along it. When the weights move outward and move the governor arms on their pivots, the sleeve is forced to slide on the shaft. This movement of the parts may be seen in the second sketch. The **detent lever** is a bar that is pivoted to some stationary part of the engine, with one end in the second groove of the sliding sleeve; any movement of the sleeve thus causes a movement of the detent lever.

When the engine is running at its normal speed, or at a lower speed, the parts are in the position shown in the first sketch. When the speed increases and goes above normal the weights fly out, and move the sliding sleeve along the shaft. This causes the detent lever to move, so that a steel plate on its upper end, called the **detent**, catches under another steel plate attached to the push rod that opens the exhaust valve. This position is shown in the second sketch. With the push rod caught on the detent the exhaust valve cannot close, and there can be no power stroke because mixture will not be drawn into the cylinder. The speed of the engine consequently falls off. When it gets down to normal the weights can no longer keep the springs stretched, and they move back to their first position, as a result of which the sliding sleeve moves back, and in turn moves the detent away from the push rod. This permits the engine to take up its cycle once more.

The tension of the springs may be changed

by means of the adjusting nut; the stronger they are the higher the speed of the engine must be before the weights fly out sufficiently to cause the detent to catch the push rod.

Figure 71 shows a **ball governor**, which is mounted on a vertical shaft. The governor weights and the sliding sleeve revolve with the shaft, and on top of the sliding sleeve is a ball bearing so that the sleeve may revolve freely against the metal plate, or **throttle**. The throttle may slide up and down, but the rest of the parts are stationary. The pressure of the spring against the throttle tends to hold the sliding sleeve down, in position A. When the shaft revolves the governor weights tend to fly outward, but in order to do so they must raise the sliding sleeve against the pressure of the spring.

The tension of the spring may be adjusted to permit the weights to move the sliding sleeve at any engine speed that may be desired.

The throttle is placed in the vaporizer in

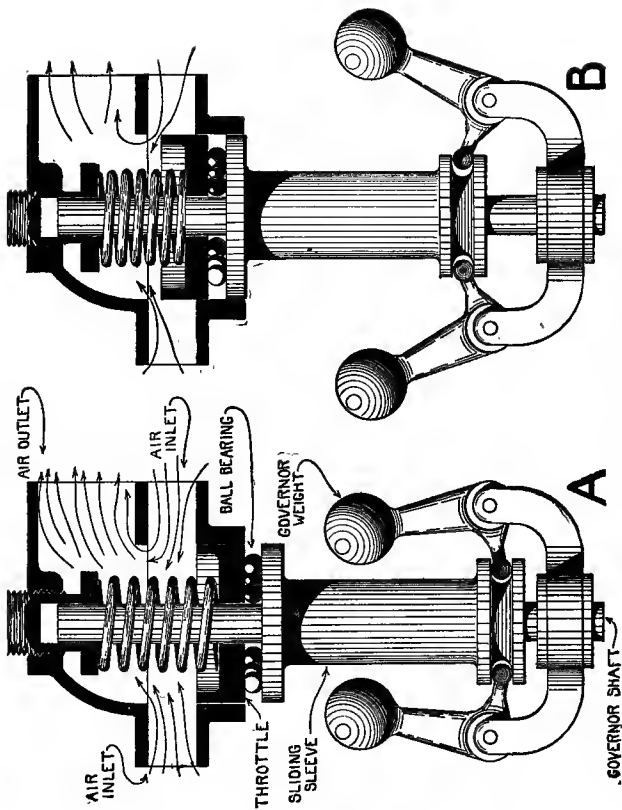


FIG. 71 — RATT GOVERNOR.

such a manner that it may close or open the air inlet. When the engine is running at normal speed or at less than normal, the throttle is in position A, and the air inlet is wide open. When the engine speed becomes too high the governor causes the throttle to rise, and to obstruct the air inlet, as shown in position B. The supply of air to the cylinder is thus reduced, and the power strokes consequently have less force; this results in the slowing down of the engine.

When the speed drops to normal the spring forces the sliding sleeve back to its original position, and the throttle again opens to admit full charges to the cylinder.

One or the other of these two governor controls is used on practically all small stationary engines. The first, which slows down the engine by interfering with the cycle, is called the **hit-or-miss** governor, and it is sometimes made more positive by an attachment that locks the inlet valve in the closed position. An arrangement of this sort is shown in Fig-

ure 15. On engines with battery ignition it is usual to provide a switching device that breaks the battery circuit when the exhaust valve is open, thus saving current by preventing the production of ignition sparks when the governor is operating. A device of this sort is quite unnecessary when a magneto is used, because its current supply is unlimited.

CHAPTER XII

CARE AND MAINTENANCE

CLEANLINESS

IF one thing is more important than another in the care of an engine, that thing is cleanliness. At the end of every day's run the engine should be wiped off, for if dirt and grit collect they will work their way into the moving parts and cause rapid wear, and may also interfere with their operation. This is especially true in the case of portable engines, which are used out-of-doors, and are covered with dust and sand whenever the wind blows.

It is easy to get into the habit of wiping the engine at the end of each day's run, and this has the added advantage of exposing

loose nuts or other parts before they have time to do any damage.

OPERATING IN COLD WEATHER

It will be somewhat more difficult to start an engine in cold weather than when the weather is warm, because the gasoline will not vaporize so easily. In order to make the gasoline vaporize it must be heated, and the safest way of doing this is by hot water. It is exceedingly dangerous to heat the vaporizer with a torch or any other open flame.

Gasoline may be heated by placing a bottle of it in hot water, or the engine may be heated enough to make starting easy by pouring hot water in the water jacket.

Another way of starting a cold engine is to soak a rag or a bunch of waste in gasoline, and to hold it at the air intake while the engine is being cranked.

It should be remembered that lubricating oil thickens when it is chilled, and that there-

fore the oiler adjustments must be opened wider in cold weather than in warm. The oiling should be very carefully watched when the engine is run in cold weather.

When water is chilled it contracts, but at the moment when it turns to ice it expands suddenly and powerfully. If it turns to ice in the water jacket the expansion will be sufficient to split the iron; and this injury will put the engine out of commission. The repair will usually require the fitting of a new cylinder or cylinder head.

The surest way of preventing the freezing of water in the jackets is to drain off the water whenever there is the slightest possibility of the temperature dropping to the freezing point while the engine is standing idle.

If water is scarce, and cannot be wasted, it can be prevented from freezing by adding calcium chloride to it; this chemical is inexpensive, and is to be used as follows:

3½ lbs. to the gallon of water prevents freezing to 10 degrees below zero.

4 lbs. to the gallon of water prevents freezing to 20 degrees below zero.

ADJUSTING THE VIBRATOR

The vibrator of a jump spark coil is always provided with an adjustment by which the blade may be made stiff or weak, and the blade must be carefully adjusted in order to get a good spark, and to avoid wasting the battery current. If the blade is stiff a great deal of current will be used in magnetizing the core intensely enough to make it move, and a stiff blade will also cause the platinum points to burn very rapidly. If the blade is weak the feeble magnetism that will make it move may not be sufficient to produce a sparking current in the secondary winding of the coil. The blade should be so adjusted that the coil will give a good spark, but should use as little battery current as possible.

Before adjusting the blade see that the

platinum points are clean and flat, so that they make a good contact. Then unscrew the adjustment until the platinum points separate, and close the switch. Screw down the adjustment, and as soon as the platinum points come into contact the blade will begin to buzz, but the buzz will be feeble. Start the engine, if it is possible to do so on the weak spark that the coil will then be giving; if it will not start screw down the adjustment until the coil gives a starting spark. When the engine is running change the adjustment until the blade is as weak as it can be without causing the engine to miss.

When the vibrator is properly adjusted the lock nut or set screw should be tightened to prevent the adjustment from working loose.

IGNITION WIRING

If the engine is wired with bell wire, in which the copper is in one piece, it will give trouble sooner or later, for the vibration of the engine will continually bend the wire

back and forth and finally cause it to break. Much trouble will be avoided by replacing the bell wire with stranded cable, such as is used on automobiles, which is so soft that bending will not injure it. With stranded cable, however, great care should be taken to prevent the ends from fraying and coming into contact with metal that would cause a short circuit.

PIPE CONNECTIONS

In making up gasoline pipe connections the threads should be painted with thick shellac as they are being screwed together, in order to prevent leakage. White lead and red lead are not satisfactory, because the oil in them will be attacked by the gasoline. At a pinch soap can be used, with good results.

GASKETS

A gasket is used to make a tight joint between two pieces of metal that are screwed or bolted together, and the most important gas-

ket is the one between the cylinder and the cylinder head. Because of the heat and pressure to which this gasket is subjected the best material to make it of is asbestos sheeting molded over wire gauze. The gasket must be cut with the greatest care to the shape of the water holes and bolt holes as well as to the inside and outside of the cylinder. The edges should be smooth, for rough or ragged edges will give trouble.

If asbestos sheeting cannot be obtained a smooth and unwrinkled piece of stout wrapping paper may be used, one side being coated with thick shellac and the other with white lead. It should be placed in position while the shellac is still wet, and with the shellac next to the cylinder.

The cylinder and cylinder head should be clean, and absolutely free from dirt and grit, before the gasket is put in place. When the gasket is in place the cylinder head may be put on, and should be driven down with a hammer and a block of wood. All of the

holding nuts may then be run down with the fingers, and when they all begin to bear on the cylinder head they should be tightened little by little with a wrench. Each nut should be given a half-turn at a time, so that all parts of the cylinder head are drawn down equally. If one nut is tightened while the others are still free the subsequent tightening of the others is likely to spring the cylinder head or distort the gasket.

When all of the nuts are tight the engine should be run for not more than one minute, with no water in the water jacket. This will heat the cylinder head and the bolts that hold it in position; and the consequent expansion of the bolts will permit the nuts to be drawn up tighter.

OVERHAULING AN ENGINE

After a season of hard work the engine will probably require overhauling, and as this is not a difficult operation it should not be put off until the engine is in serious need of it.

As a first step the engine should be examined with great care in order to determine the work that is to be done. Leaks in the gaskets, outlet and exhaust pipes, the gasoline line, etc., should be located and marked; lost motion should be noticed, and in general the work to be done should be determined before any of the engine parts are removed.

It should be remembered that to get the best results each nut, bolt and other part should be returned to the identical position from which it was taken, which will require the marking of each part as it is removed. In the case of timing gears they should be marked with a prick punch, two adjoining teeth in one gear being marked and the tooth of the other gear that is between them also being marked. It is quite usual for manufacturers to provide marks of this sort on the timing gears, and in reassembling the engine it is only necessary to mesh the gears so that the marked tooth of one goes between the two marked teeth of the other.

Four or five boxes should be provided, one for the parts of the gasoline line, i. e., the piping, the mixer, the gasoline pump, etc.; the second box for the parts of the ignition system, the third for the parts of the valve mechanism, and so on. The bolts or nuts that secure the exhaust pipe may appear to be the same as those used in securing the inlet pipe, but in reality may differ so considerably that one may not be substituted for the other. This condition may apply to all parts of the engine, and it will be seen that these parts must be kept separated. As each part of the engine is removed it should be cleaned, and this is best done with kerosene and a stiff brush.

As a first step all of the external parts of the engine should be removed, i.e., the ignition system, the gasoline system, the valve mechanism and other parts, so that finally only the bare cylinder is left. As each part is taken off it should be cleaned and put in good condition, so that the mixing valve, for

instance, will be cleaned and made ready for use as soon as it is taken off and before any work is done on the cylinder.

If the engine has a removable cylinder head it should be taken off, care being exercised to preserve the gasket. The inside of the cylinder head should be cleaned from carbon, the water spaces should be examined and cleaned if necessary, the valves should be ground in, etc. The piston and connecting rod may then be removed, the piston being examined for faults that might cause a lack of compression. If the piston and cylinder are in good condition all of the piston rings should be bright all over and should be free and springy in their grooves, with only the very slightest lost motion up and down. If the rings are black and streaked it indicates that the pressure is blowing past, and that therefore there is a loss of compression. This difficulty may be due to a piston ring sticking in its groove or to weakness.

If the ring does not move easily and is evi-

dently stuck, the entire piston should be placed in a pail of kerosene for a half hour or so to loosen the carbon that is lodged in the grooves. This treatment is frequently sufficient to loosen the rings and to permit the carbon to be washed out. If the carbon is baked hard the rings must be taken off. As the rings are made of cast iron and are thin, they are extremely brittle, and will break like glass if they are not carefully handled. They are sufficiently elastic to be sprung over the upper part of the piston, but they must not be sprung open too wide.

In order to take the rings off three strips of thin brass should be provided, $\frac{1}{2}$ inch wide and 6 to 8 inches long. One end of the top ring should be pried out of its groove with the point of a knife, and one of the pieces of brass should be slipped under it to form a bridge across the groove. This strip of brass should then be worked half way around the piston, a second strip of brass being slipped under the end of the piston ring. The other

end of the piston ring should then be carefully pried out of its groove and the third strip of brass slipped under it. The ring will then be entirely out of its groove and resting on the brass strips, and may be slid upward and off the piston. The second and third rings should be removed in the same manner, and it will be found that the brass strips will prevent them from snapping into the upper grooves.

As each ring is removed it should be marked so that it may be returned to its particular groove and with the proper side down. It will be noticed that one side of the ring is smooth and polished; this is the side that goes down. The rings should not be marked with a prick punch as this will break them; they should be marked with chalk or a piece of paper should be tied to each one.

In scraping the carbon from the rings and the grooves a steel tool should not be used, as it will scratch the metal. A piece of hard

wood should be whittled down to a chisel edge and used for this purpose.

The rings are almost always pinned to prevent them from sliding around in their grooves. These pins are screwed or riveted into the piston, and they should be examined to see that they are tight. If they are loose they will either work their way through the piston and into the crank case, or will back off and scratch the cylinder wall.

If one side of the piston above the end of the wrist pin is bright and shiny and the opposite side of the piston below the end of the wrist pin is also shiny, it indicates that the wrist pin hole has not been drilled true in the piston or that the connecting rod is bent. This condition will cause the engine to overheat and will also result in a loss of power. If the difficulty is due to the inaccurate drilling of the wrist pin hole it can only be corrected by supplying a new piston that is more accurately machined. If the connecting rod is bent it should be straightened in a properly

equipped machine shop, for it is a job that requires an expert.

In taking off the connecting rod from the crank shaft care should be taken to notice the exact location of the shims, and this is also the case with the crank shaft bearings. If it is necessary to remove the shims they should be removed equally from the two sides of the bearing cup. Poor results will be obtained if one side of the cap is lower than the other.

In reassembling the engine all the parts should be thoroughly cleaned, for a chip of metal or grain of sand under a gasket or between ground surfaces will prevent a proper fit and will cause a leak. Before attaching bolts and nuts the threads should be oiled with machine oil, as this will permit them to go on evenly and without binding. It will also tend to prevent their rusting in place.

A majority of the nuts and bolts of an engine are subject to vibration and may easily become loosened. This should be prevented

by the use of lock nuts, cotter pins or lock washers.

VALVE GRINDING

When an engine has been in use for some time the valves will begin to leak, and will require grinding. In order to grind a valve the valve disk must be exposed; on some engines this will necessitate the removal of the cylinder head, while on others the valve cages may be withdrawn or the valve caps removed. The valve springs must be taken off, and the valve itself drawn out of its guide.

The valve seat is to be moistened with oil and a little flour of emery dropped on it; grinding is accomplished by turning the valve on its seat so that the emery cuts into the valve disk as well as the seat, and wears them both to a smooth surface. The valve should not be revolved continuously in one direction, but part way around in one direction and then as much in the other. A carpenter's brace with a screwdriver bit to fit in the slot

in the valve disk is a good tool to use, and it should be remembered that to get the best results very little pressure should be exerted. After every few turns the valve should be lifted and turned to a new position on its seat, the wear thus being distributed.

In order to test the valve the emery and oil should be washed from the valve disk and seat with gasoline, and marks should be made all around the seat with a lead pencil. The valve should then be replaced, and given a quarter-turn with light pressure. If the grinding is completed the pencil marks will be removed entirely around the seat. However, it is not necessary for them to be removed from the entire surface of the seat; if the valve makes contact all the way around, but only for a portion of the width of the seat, it will be sufficient to hold the pressure.

When the grinding is finished great care should be taken to remove every trace of the emery.

MENDING A BROKEN PIPE

A split in a brass or copper pipe may be permanently repaired by winding No. 12 or No. 14 bare copper wire around the pipe for the length of the split, and for a few turns be-

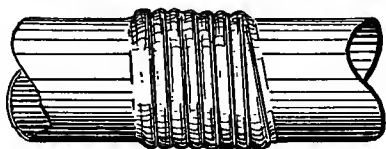


FIG. 72.—MENDING A BROKEN PIPE.

yond it at each end. The turns should be wound close together, and the ends secured to prevent them from unwinding. The entire winding should then be soldered, as shown in Figure 72.

CLEANING THE WATER JACKET

When an engine has been in use for a season or two it is not unusual for the water jacket to become more or less filled with sediment that forms a hard scale on the cylinder.

This is particularly liable to be the case when "hard" water is used.

The scale prevents heat from passing to the cooling water from the cylinder, and is therefore responsible for the overheating of the engine. In order to remove it fill the water jacket with a mixture of muriatic acid and water, using one part of acid to four parts of water if the scale is thick and hard, and one part of acid to eight parts of water if the scale is thin and soft. Let it stand for from twelve to forty-eight hours. The scale should wash off when the jacket is flushed out; if it does not repeat the treatment.

BACKFIRING

It occasionally happens that a mild explosion will occur in the inlet pipe, accompanied by a puff of smoke or possibly a jet of flame at the air inlet, and this is called a backfire. This is usually due to the mixture being so poor in gasoline that it burns very slowly, and is still burning when the inlet valve opens to

admit a fresh charge. The entering charge is ignited and explodes in the inlet pipe.

Backfiring from this cause may be prevented by opening the gasoline valve a little to make the mixture richer, for a rich mixture burns rapidly enough to be entirely consumed by the time that the inlet valve opens.

Another cause of backfiring is a worn and leaky inlet valve, or a sticking valve stem, for in such a case the flame may blow through the valve to the inlet pipe. Backfiring from these causes will be accompanied by a loss of compression.

FIRE

In case of a gasoline fire waste no time with water, but smother it with sawdust, flour, a blanket, or anything else that will shut out the air. Gasoline is lighter than water, and will float on it; if the gasoline is burning water will spread the fire, and will make matters worse instead of better.

Gasoline vapor is heavier than air, and will

sink to the floor if there is no draft to keep it stirred up. If gasoline has been spilled in a closed room the doors and windows should be opened to clear out the vapor. If this is not done the room will contain an explosive mixture that is capable of doing great damage if it is ignited.

REPAIR JOBS

A small crack in a water jacket may be mended by filling the jacket with a strong solution of sal ammoniac in water. This chemical will cause the iron to rust, and will thus close the crack. If the crack is too large to treat in this manner scrape the metal around it, inside as well as outside if possible, and heat it with a blow torch or other means. This will expand the metal and open the crack sufficiently to permit it to be filled with a cast iron cement, of which a number of brands are on the market.

A screw that is rusted in place may be loosened by holding a red-hot piece of iron

against its head until it is hot. The heat will expand it and loosen it sufficiently to permit it to be unscrewed.

Rusted nuts should have kerosene run on them. After waiting a few minutes to let the kerosene soak into the rust, hold a block of iron against one side of the nut and strike the opposite side a few sharp blows with a hammer. This should loosen the nut sufficiently to permit it to be removed.

A stud is a bolt without a head, and threaded at both ends; studs are frequently used for cylinder heads, crank cases, etc. Having no heads, they cannot be turned with a wrench, and a pipe wrench or gas pliers will injure the threads. To turn a stud run two nuts down on the free end, and jam them together by the use of two wrenches. To unscrew the stud put the wrench on the lower nut, and to screw it in use the upper nut.

If a stud or bolt is broken off in a casting, with the break below the surface, it can be removed by drilling a hole in it, and driving

into the hole the pointed or handle end of a file. The sharp corners of the file will bite into the metal of the screw, and will grip it sufficiently to unscrew it.

A pulley that is stuck on its shaft may be loosened by applying kerosene at the ends and set screw holes. A badly stuck iron pulley may be loosened by heating the hub with a blow-torch.

CHAPTER XIII

CAUSES OF TROUBLE

ANY part of an engine may go wrong, and the engine user should know the possible trouble that each part may give in order to keep his engine running.

A loose nut or bolt is easily recognized, for it will make itself known by play or lost motion that may be seen, or by noises that may be heard.

Defects of ignition, carburetion and compression are not so apparent, and must be hunted for.

DRY CELLS

Dry cells should be kept in a tight box, and protected from dirt and dampness. If their pasteboard jackets become wet they will form a conductor between adjoining cells, and cause a waste of current. If the terminals

are oily, dirty, or loose, the current may not be able to pass to the wire.

A dry cell will give its most intense current when it is new and will waste away with age, even if it is not being used; when buying cells, fresh ones should always be insisted on.

When a dry cell has been in use for some time it becomes exhausted; it will give a current for a little while, and will then fail. If it is permitted to stand idle for an hour or so it will again give a current, but only temporarily. An exhausted cell is useless, and should be replaced.

If a dry cell is chilled it will not give as intense a current as when it is warm.

A dry cell will refuse to give a current from any one of the following causes:

Exhausted.

Connecting wires broken or loose.

Terminals dirty.

Improperly connected.

Accidentally short-circuited.

Chilled.

WIRING

All connections should be tight and clean; if a wire is attached to painted metal the paint should be scraped off and the surface rubbed with emery cloth.

Bell wire may break inside the insulation; the break may not be visible, but can be located by feeling the wire.

When stranded cable is used one of the strands may escape from under the nut and make a short circuit.

VIBRATOR COIL

A vibrator coil should be kept dry, and free from dirt, and the connections should be clean and tight.

As a result of use the platinum points will become burned and rough, and the blade will then work improperly.

There will always be a little sparking at the platinum points; when this becomes excessive

the points should be cleaned. If necessary, they may be smoothed off with a very fine flat file or fine emery cloth, great care being taken to have them flat and true to each other. If the sparking continues after cleaning and smoothing the points, and the adjustment is correct, it is a sign of internal trouble that requires the return of the coil to the makers.

A vibrator coil will refuse to work from any one of the following causes:

Platinum points dirty, oily or worn.

Vibrator out of adjustment.

Current too weak.

Connections loose or dirty.

Vibrator blade loose.

MAKE-AND-BREAK COIL

A make-and-break coil will give trouble through loose or dirty connections, or through being wet.

SPARK PLUGS

The spark gap should not be less than $1/50$ inch, nor greater than $1/32$ inch; the distance may be adjusted by bending the electrodes.

A spark plug will become fouled through use, and will then refuse to spark because the current will flow by the carbon deposit on the insulator instead of jumping the gap. The plug may be cleaned with gasoline and a stiff brush.

A spark plug will refuse to work from any one of the following causes:

Fouled.

Gap too wide.

Gap too small.

Electrodes oily or wet.

Insulator cracked or broken.

Outside insulator dirty or wet.

TIMER

A timer will give trouble through any one of the following causes:

Dirty.

Packed with grease that is too thick.

Timer spring weak.

Connection loose.

Slipping on shaft.

IGNITER

An igniter will give trouble through any one of the following causes:

Electrodes dirty, wet or oily.

Insulation fouled.

Insulation cracked or broken.

Out of adjustment.

Movable electrode stuck.

Springs weak or broken.

FRICTION DRIVE GENERATORS

A friction drive generator will give trouble through any one of the following causes:

Friction wheel slipping.

Governor sticking.

Brushes sticking.

Brushes dirty.

Brush springs weak.

Commutator dirty or worn.

Connections loose.

Winding burned out.

GASOLINE FEED

The gasoline will be prevented from feeding properly by any one of the following causes:

Dirt in the gasoline.

Check valves of pump not working.

Insufficient suction, due to leaking joints.

Leaking pump and connections.

CARBURETION

The mixer will give trouble through any one of the following causes:

Dirt in the nozzle.

Water in the gasoline.

Wrong adjustment.

Air inlet clogged.

Air leak in inlet pipe.

VALVES

The valves will give trouble through any one of the following causes:

Dirty or rusty stems, causing valves to stick.

Springs too weak.

Valves worn.

Not timed correctly.

COMPRESSION

A loss of compression will be caused by any one of the following defects:

Leaking valves.

Weak valve springs.

Leaking spark plug or igniter.

Leaking gasket.

Leaking petcock.

Worn or scratched cylinder walls.

Worn or scratched piston rings.

Piston rings stuck or broken.

LUBRICATION

Trouble with lubrication will be due to any one of the following causes:

Oiler dirty.

Incorrect oiler adjustment.

Oil of wrong kind or thickness.

Oil thickened by cold.

WATER COOLING

Defective water cooling will be due to any one of the following causes:

Insufficient water.

Water jackets clogged with dirt, or with deposit from hard water.

Water pump clogged.

Ignition spark timed too late.

AIR COOLING

Defective air cooling will be due to any one of the following causes:

Flanges dirty.

Fan belt slipping.

Fan blades bent.

Ignition spark timed too late.

EXHAUST

A free exhaust will be prevented if the exhaust pipe and muffler become clogged.

CHAPTER XIV

EFFECTS OF TROUBLE

EVERY case of trouble has its reason, and as a general thing the reason may be determined by observing the action of the engine.

In looking for engine trouble it must be remembered that the engine cannot help but run if it receives a proper charge of mixture, and if the mixture is compressed and ignited correctly; provided, of course, that the bearings are not too tight, the crank shaft is not broken, or some other vital point is not defective.

The following list shows the causes of defective engine operation:

ENGINE WILL NOT START

No ignition.

No carburetion.

No compression.

ENGINE STARTS, BUT WILL NOT CONTINUE
RUNNING

Too heavily loaded.
Exhausted battery.
Dirt in spray nozzle.

EXPLOSIONS STOP ABRUPTLY

Broken wire in battery circuit.

EXPLOSIONS WEAKEN AND STOP

No gasoline.
Exhausted battery.
Loose timer.

ENGINE MISSES EXPLOSIONS

Governor operating.
Sticking vibrator.
Loose connection.
Dirt or water in gasoline.
Sticking valve.
Water in cylinder.
Dirt in timer.

ENGINE LOSES POWER, EXPLOSIONS BEING
REGULAR

Too heavily loaded.
Weak compression.
Ignition out of time.
Piston or bearings too tight.
Insufficient lubrication.
Defective cooling.

ENGINE OVERHEATS

Defective cooling.
Insufficient lubrication.
Ignition too late.

“POPPING” IN MIXER

Mixture too weak.
Inlet valve sticking.

EXPLOSIONS IN MUFFLER

The result of missing explosions.

KNOCKS AND POUNDS

Ignition too early.

Loose bearings.

Loose cylinder.

Loose flywheel.

HISSING

Leaks of compression.

Leaks in inlet or exhaust pipes.

ENGINE KICKS BACK ON STARTING

Ignition too early.

ENGINE WILL NOT STOP

Heavy carbon deposit in cylinder.

Spark plug electrodes so thin that they glow and ignite the charge.

Frayed end of packing or point of metal that becomes overheated and ignites the charge.

BLACK SMOKE AT EXHAUST

Mixture too rich.

BLUE SMOKE AT EXHAUST

Too much oil.

CHAPTER XV

TESTING FOR TROUBLE

WHEN there is trouble with the ignition system the cause is not always easy to see, and it will be necessary to test the various parts in order to tell what is at fault. It is far better to do this systematically than to go at it haphazard in the hope of locating the fault by chance or by guess. It will be worse than useless to change the adjustment of the vibrator unless you are certain that it is the vibrator that is making trouble, but none the less, many engine users try to locate trouble in just that aimless way. Many a man has gone to the store for a new battery when his neglect to turn on the gasoline was the reason why his engine would not run.

If the following tests are carried out they will locate the fault exactly:

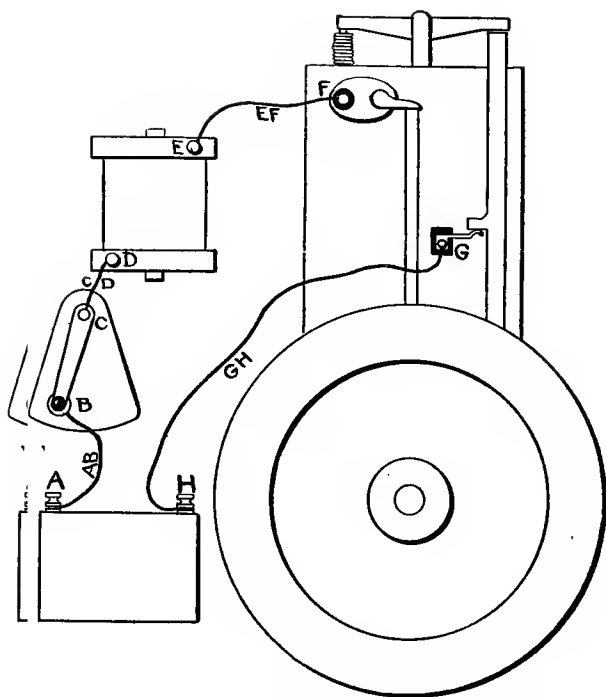


FIG. 73.—DIAGRAM OF MAKE-AND-BREAK SYSTEM.

MAKE-AND-BREAK SYSTEM

Let us suppose that there is trouble with a make-and-break system, operating with battery and coil. Figure 73 is a diagram of this system, and it shows the battery with one terminal A connected to terminal B of the switch, switch terminal C connected to one terminal D of the coil, and the remaining terminal E of the coil connected to the insulated electrode F of the igniter. From the metal of the engine the current returns to the battery by the ground wire G H, the end G being connected direct to the metal of the engine, or, as shown in the diagram, to a switch device that breaks the circuit when the push rod moves to open the exhaust valve.

There is a defect in one of these parts, but all that we know about it is that the engine will not run, although it is getting a proper mixture and the compression is good. As the first test, touch one end of a piece of wire to terminal F of the igniter, and wipe the other end across any unpainted metal part of the

engine; if you get a good spark it shows that the battery is giving a current, and that the current is flowing properly over all parts of the system, with the exception of the igniter. If the igniter will not give a spark when you try to start the engine your test proves that the trouble is in the igniter itself.

If this test does not show a good spark the trouble must be looked for in one of the other parts of the system, or possibly you have forgotten to close the switch; that is a thing that any one is liable to do.

Hold one end of your piece of wire firmly on the H terminal of the battery, and wipe the other end across the A terminal; if the battery is in good condition you will get a small crackling spark. If you get no spark look for loose or broken battery connectors; if these are all right you can make up your mind that the battery is exhausted.

If you get a spark at A, continue to hold one end of the wire on H, and wipe the other end across terminal B. A spark at A and no

spark at B shows that the wire AB is broken or that its connections are loose or dirty. In the same way a spark at B and none at C shows that something is wrong with the switch, and a spark at C and none at D shows that there is something the matter with wire CD.

When you touch the wire to the terminal E of the coil you get a much more intense spark, for now the coil is working. A spark at E shows that everything is in good condition up to that point, and if then you get no spark at F you prove that the trouble is in the wire EF. You have already made a test with F connected to the metal of the engine, and did not obtain a spark; now crank the engine slowly until the igniter is making contact, and then wipe one end of the wire across any bright metal part of the engine, the other end of the wire still being held on terminal H of the battery. The spark that you will get proves that the trouble is in wire GH, which is broken or poorly connected.

JUMP SPARK SYSTEM

The jump spark system with battery and vibrator coil can be tested in an equally simple way, in spite of the fact that instead of one circuit it has two; the circuit over which the battery current flows, and the circuit of the sparking current. Figure 74 shows the battery circuit to be made up of the battery, the wire AB, the switch, the wire CD, the primary winding of the coil and the vibrator, the wire EF, the timer, and the ground wire GH.

You begin your test with the knowledge that unless the coil is defective it will give a spark whenever the vibrator buzzes. So close the switch and turn the flywheel once for a 2-cycle engine, and twice for a 4-cycle engine, listening for the buzz of the vibrator. If it buzzes in the usual way it shows that the battery is giving current, and that the current is flowing properly through the coil and timer. If the engine will not run because of the lack of an ignition spark, you can be quite

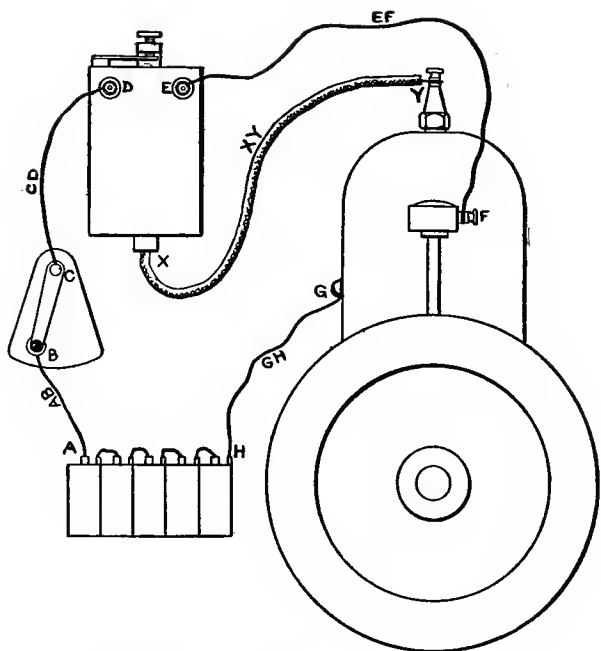


FIG. 74.—DIAGRAM OF JUMP SPARK SYSTEM.

sure that the spark plug is defective, or that the sparking current is leaking from the wire XY.

To test the plug unscrew it, and lay it down on the cylinder so that only the screw-threaded part touches the metal; then crank the engine slowly, and when the vibrator buzzes watch for a spark at the plug electrodes. Do not be satisfied with any but an intense and brilliant spark; it is easier for the spark to form in the open air than in the cylinder during the compression stroke, and a current that gives only a weak spark in the open air may not give any spark at all in the cylinder.

If the vibrator does not buzz when you turn the flywheel, make sure that the switch is closed, and examine the vibrator. Touch the blade to see that the points are not stuck together, and clean the points if they are dirty or oily.

If still there is no buzz touch one end of a piece of wire to terminal F of the timer, and

wipe the other end across any unpainted part of the engine, in order to cut the timer out of the circuit. If this makes the vibrator buzz it shows that the timer is dirty, or that for some other reason it is not making contact as it should.

If there is no buzz when you make this test hold one end of the wire firmly on terminal H of the battery, and wipe the other end across the A terminal; if the battery is in good condition you will get a small crackling spark. If there is no spark either the battery is exhausted or the battery connections are loose or broken.

If you get a spark at A continue to hold one end of the wire on H and wipe the other end across terminal B. A spark at A and no spark at B shows that wire AB is broken or that its connections are loose or dirty. In the same way a spark at B and none at C shows that something is wrong with the switch, and a spark at C and none at D shows that the wire CD is defective.

If you get a spark at E, but the vibrator does not buzz, it will be because the adjustment is screwed down so far that the blade cannot move, or else that the platinum points are stuck together.

If the vibrator buzzes when you touch the wire to terminal E, but there is no buzz when you touch the wire to terminal F, look for trouble in wire EF. If there is a buzz when you touch the wire to terminal F, but there is no buzz when you turn the flywheel, it shows that the trouble is in the ground wire GH, or in the terminal G.

FRICTION DRIVE GENERATORS

An engine fitted with a friction drive generator usually has a battery system for starting; in such cases the generator may be tested while the engine is being run on the battery. Disconnect from the switch the wire leading from the generator, and wipe the bare end of the wire across any bare metal

part of the engine. If the generator and its wires are in good condition bright sparks will be produced. If there are no sparks wipe the wire across the other terminal of the generator, and sparks at this point will indicate that the wire from that terminal to the engine is loose or broken. If no sparks are produced the generator should be looked over for a slipping drive wheel, a stuck governor, dirty or stuck brushes, weak or broken brush springs, or a dirty or worn commutator.

COMPRESSION

With a 4-cycle engine the test for compression is to turn the flywheel twice. If the compression is good the wheel will turn easily for a revolution and a half, and will then turn hard, with the feeling that it is turning against a spring. If the wheel turns easily for two revolutions it indicates that the gas is leaking out of the cylinder instead of being retained. The leak may be due to a stuck or

worn valve, a loose spark plug, igniter, valve cage or pet cock, to a leaky gasket, or to stuck or broken piston rings.

In a 2-cycle engine the compression should be perceptible once during every revolution.

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